PRACTICAL

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ELECTRONICS

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SCIENCE & TECHNOLOGY

PE VIGILANTE CAR ALARM

PE 30+30 STEREO AMP

SWITCH MODE POWER SUPPLIES

INDUCTIVE LOOP REMOTE CONTROL

DESIGN – DC MOTORS
TYPES AND FEATURES OF COMMON MOTORS

COMPUTING – DUAL OPTION
EPROM PROGRAMMER FOR THE AMSTRAD

TECHNOLOGY – SENSORS
ESSENTIAL INTERFACE DEVICES EXPLAINED

EXPERIMENTAL ELECTRONICS
AND PRACTICAL APPLICATIONS – ALL IN THIS ISSUE

PLUS:

- ★ SPACEWATCH
- ★ LEADING EDGE
- ★ INDUSTRY NEWS
- ★ CIRCUIT IDEAS
- ★ LOGIC PUZZLE

THE SCIENCE MAGAZINE FOR SERIOUS ELECTRONICS AND COMPUTER ENTHUSIASTS

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Keep your car alert to intruders – build a box to fox them!

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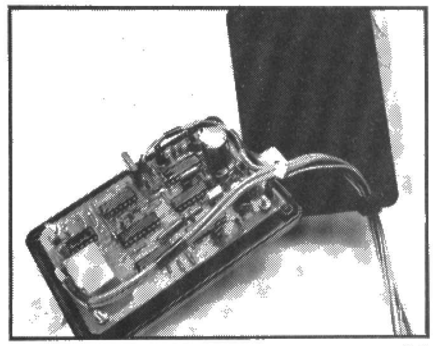

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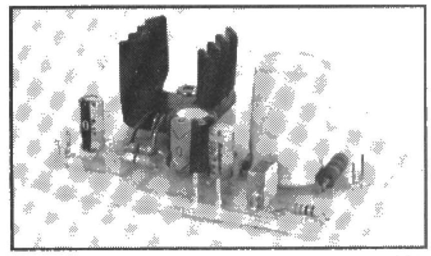

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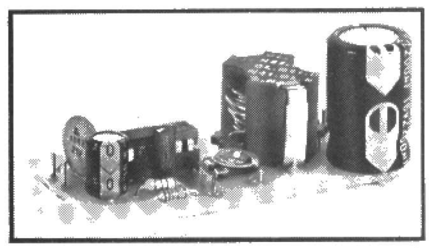

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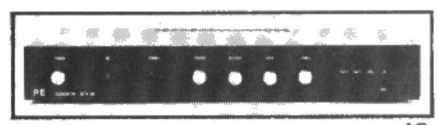

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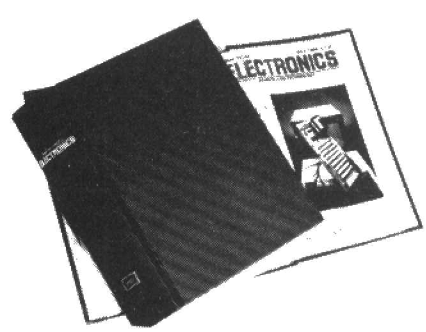


THE SCIENCE MAGAZINE FOR SERIOUS ELECTRONICS ENTHUSIASTS

CATALOGUE CASEBOOK

Last month we received the following catalogues and liturature:

Eagle International has launched into 1987 with a new look. Their colourful 40 page all-range catalogue also announces some **major new products. Eagle International,** Unit 5, Royal London Estate, 29/35 North Acton Road, London NW10 6PE.

Fane, the manufacturers of professional audio components, high power and heavy duty speakers, have sent a list of over **20 new products** for 1987 that will be introduced at the Frankfurt Fair. **Fane Acoustics Ltd.,** 286 Bradford Road, Batley, West Yorkshire, WF17 5PW.

Flight Electronics' 5th edition 1986/87 colour illustrated catalogue of micro electronic systems and instrumentation, with particular emphasis on **training systems.** Flight Electronics Ltd., Flight House, Ascupart Street, Southampton, Hants, SO1 1LU.

Greenweld's Kit Cat features **top quality** kits by Velleman, Pantech and Greenweld. The catalogue is liberally illustrated with photographs and drawings. **Greenweld Electronics Ltd.,** 443 Millbrook Road, Southampton, SO1 0HX.

The **Inmac** 140 page January 1987 catalogue is a computer users ideas book of instant mini/micro **computer accessories** and cables – a remarkable product source. **Inmac (UK) Ltd.,** 16 Silver Road, London W12 7SG.

Instrument Rentals' 100 page 1987 catalogue of electronic test and measurement equipment includes more than **1000 different manufacturer models.** It also contains sections on computers, industrial and survey equipment for hire and second user sale. **Instrument Rentals,** Dorcan House, Meadfield Road, Langley, Slough, SL3 8AL.

MBS claim that their telephone number is the only one you will ever need. If you are after **computer accessories,** their Jan-Feb 87 catalogue is worth studying. **MBS,** Maxted Road, Hemel Hempstead, Herts, HP2 7BR.

Phonosonics' current catalogue contains **over 70 kits** for music, sound effects, and computer projects. Additionally **Geiger counters** in both kit and ready built form are prominently emphasised. **Phonosonics,** 8 Finucane Drive, Orpington, Kent, BR5 4PE.

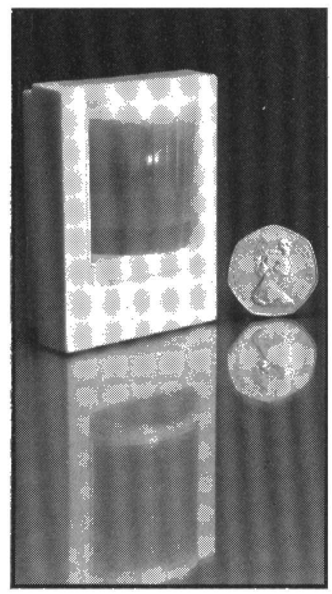
Technomatic's new extensive list of computers, printers, modems, disc drives, and a multitude of electronic components, is **vital source material** for any quality-seeking electronics constructor or computer user. **Technomatic Ltd.,** 305 Edgware Road, London W2.

WHAT'S NEW

Small Detector

A new passive infra-red intruder detector has been announced by Riscomp Limited. Called the RP33, it operates by sensing an intruder's body heat within the protected area. The detector, which uses a Fresnel lens, provides volumetric coverage through an 85 degree angle, with twenty four zones over ranges of twelve metres. The miniature size of 80 x 60 x 40mm permits it to be easily installed on any flat surface or corner location, with vertical adjustment of the detection pattern over a 10 degree range to achieve the most effective coverage.

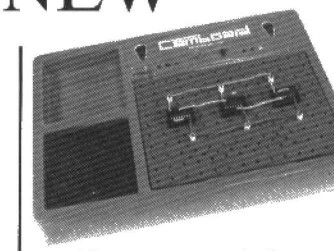
A further aid to installation is a switchable walk test indicator, which provides a visual indication of the effective range. Using a 15mA operating current from a conventional 12V supply, the unit is suitable for use in most security installations. It costs £23.95 plus VAT. A leaflet is available from Riscomp with full installation instructions.



Chip Board

CAMBOARD of Cambridge are producing a range of solderless breadboard modules designed to overcome some of the space and connection problems associated with using breadboards for prototyping and testing circuits.

The basic breadboard unit provides a removable plugboard grid of ten by fourteen connecting holes in a specially made base tray, with a power busbar, power connections and extra mounting holes for discrete components integrated into the tray. There are also two sensibly-sized component holders, one fitted with conductive foam to protect i.c.s. and other static-



sensitive components before connection. The boards can be mounted at 90 degrees or 180 degress to the user for easy access, and the board can be stored upside-down in its tray if necessary to protect components mounted on it.

The basic unit can in addition be supplied in packs with one, three or seven 16-pin i.c. sockets.

One advantage of the plugboard arrangement over traditional stripboards is that this gives the space and flexibility to translate a design straight from schematic to working prototype without the necessity for designing around copper strip connections. Camboard also boasts a different contact arrangement from most breadboards. Normal breadboard clips make contact with the thin edge of i.c. pins, which are narrow, and roughened by the stamping process. Camboard's sockets make contact with the broad, smooth edge of the i.c. pins, increasing the area of contact and minimising wear on the contact plating.

Circuits can be built up on one Camboard, or over a number of separate boards.

The price for the basic unit is £4.36, excluding VAT but including carriage. Units with one, three and seven i.c. socket packs cost £4.79, £5.18 and £6.92 respectively.

P.E. Kit

AUDIOKITS, supplier of specially graded components to hifi constructors, is introducing two new audio amplifier kits during the first half of 1987.

The first, well known by now to readers of Practical Electronics, is the PE 30 + 30 slimline integrated hifi amplifier, which includes tone controls, two tape recorder connections with dubbing in both directions, and a switched MC input. The complete kit, which uses very high quality components, costs £140. A kit for the same amplifier using the very best components which can be fitted to the same board will be available later at around £330 - £350.

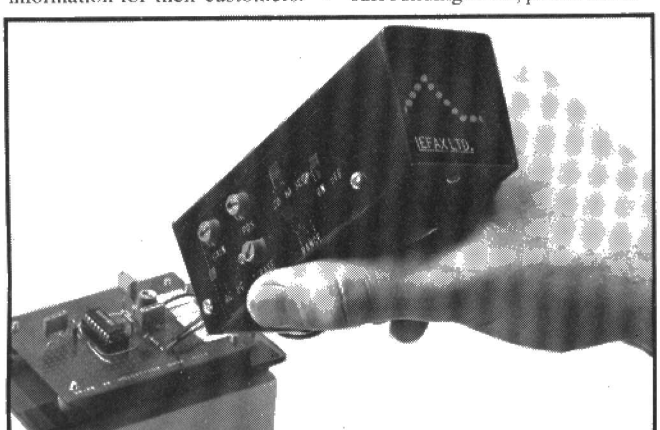
Later this year the Everyday Electronics Apex amp will be available in kit form. No further details are available at present.

Among the unusual or specialised components offered by Audiokits in 1987 are bulk foil resistors, manufactured to the highest standards of accuracy with low internal capacitance and inductance, and a very low temperature coeffficient of 4ppm/degrees C or better, from zero to sixty degrees. Extended foil capacitors are made in Britain for high precision telecommunications filter circuits: a range selected for sonic qualities is being made available, including 200pF and 470pF capacitors for MM cartridge matching, and 8nF for MC cartridge matching, as well as higher values up to 250nF.

For constructors who have problems with mechanical noise in mains transformers, Audiokits offers the same specially manufactured low noise transformers that it uses in its own kits.

To help hifi builders who to use individual components not specified in original parts lists, Audiokits has issued a set of parts price lists for various magazine amplifier projects. The next plan is to produce component application notes along the same lines, selling at between 50p and £5.00.

Audiokits were at the Hifi '87 show at the Holiday Inn in Brighton on 20-22 February, providing high quality components and technical information for their customers.



Scope In Hand

LEFAX Ltd. have developed a tiny hand held oscilloscope with a detachable probe tip. The size of the Lefax Scope-probe is only 46 by 46 by 120mm, and it can be used either in a similar way to a logic probe, or as a bench instrument with standard 'scope leads'. An internal alkaline battery allows around twelve hours continous use before it needs charging.

The 'scope has five frequency ranges, and the manufacturers say that despite the small screen, which inevitably has a restricted resolution, it can display most waveforms between 10Hz and 20kHz. A direct reading d.c. voltmeter with 0-10 v.d.c and 0-20kHz scales is built in. The controls (shown in the photograph) include a.c./d.c. input select, amp gain, Y position, mode select, sweep variable coarse and fine, range select and internal battery check.

The very small size and modest price of the Scope-Probe has been achieved by the use of a ten by fourteen l.e.d. matrix in place of a c.r.t or l.c.d. Lefax believe that the handy, portable 'scope will be beneficial to lab based users as well as to those working in repair and maintenance in the field.

The Scope-Probe will be available by mail order from Lefax, priced £89.95 exclusive of VAT, postage and packing.

Water Watcher

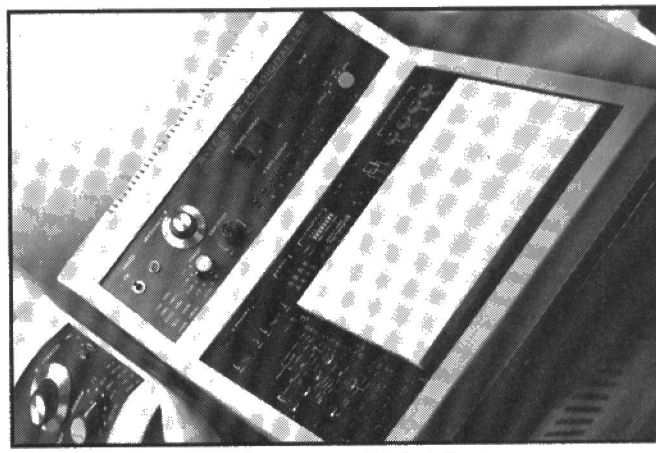
BATTELLE of Ohio has developed a wristwatch-sized 'underwater decompression computer' for undersea divers. The function of the computer is to assess the length of time and depths of water which have been dived, and to tell the diver, by means of a visual readout, when and how far it is safe to ascend through the water.

Too fast an ascent through a considerable depth of water leads to aeroembolism, a condition where nitrogen, forced into the bloodstream by the greater pressure of the surrounding water, passes out of the bloodstream in bubbles as the pressure is released. Known as 'the bends', aeroembolism can be fatal, so it is of vital importance that a diver does not rise from deep water too quickly after a period of submergance.

The wrist computer, says Battelle, will allow the diver to move independently and safely in depths up to 300 feet, keeping track of how much time has been spent at a particular depth, and how much time should elapse before a further ascent can be made.

The battery-operated computer uses 1mA to power its i.c.s., which are printed on aluminium oxide substrate one and a half inches square. The device can be used either with oxygen and helium or oxygen and nitrogen breathing mixtures, and can be used, it is said, to monitor gas pressure status under some circumstances. In addition, plug in personal computer modules can be attached to store and read out dive histories.

Battelle is working to introduce the decrompression computer into the commercial market, and would like to hear from individuals or organisations interested in working with them on this product. Information can be obtained from Battelle's London Office, from Renate Seibrasse, Operations Manager, Battell Institute Ltd., 15 Hanover Square, London W1.



Digital Desk

A totally self contained digital electronics workstation for those studying advanced electronics, or working on the prototyping of circuits, is being marketed by Flight Electonics of Southampton. The FLT-102 Digital Training Laboratory, which resembles nothing so much as a compact multi-channel mixing desk, has built into it multi-rail variable d.c. supply, a four-range digital voltmeter, function generator, seven segment displays, logic switches, funtion switches, pulse switches and logic indicators. Everything, in short, that you wish you had on your trusty low cost hand held multimeter. The difference is that the FLT-102 costs £250, and is more likely to appeal to teaching establishments and commercial

CHIP COUNT

This month's list of new component details received.

601-TYPE – DIL microfilters with good RFI screening. (3).
IMS1630 – VHS 8K x 8S RAM, requires no external clocks. (2).
MVA1000 – 75 Ohm fixed gain (12dB) 0-10MHz video amp. (3).
TP1481 – HV op-amp for ±15v to ±75v supplies, 80mA. (3).
TP1493 – Fast setting (120 nsecs) wideband (40MHz) op-amp. (3).
TP1648 – HV op-amp for ±10v to ±50v supplies, 10A. (3).
TP4192 – 12-bit A/D fast (500nS) precision converter. (1).
UMHL/UMCL – Microfilters for 7th/9th order low pass. (3).
VS618 – Lows pass video filters for analog TV improvement. (3).
WS57C191/291 – 2K x 8 CMOS RPROM. (4).
WS57C256F – 32K x 8 CMOS EPROM. (4).
WS57C43 – 4K x 8 CMOS RPROM. (4).
WS57C49 – 8K x 8 CMOS RPROM. (4).
WS57C64F – 8K x 8 CMOS EPROM. (4).

Manufacturers, and contact telephone numbers for further details. (1) Teledyne Philbrick, 01-902-1191. (2) Rapid Silicon, 0494-442266. (3) Matthey Electronics, 01-902-1191. (4) Rastra Electronics, 01-748-3143.

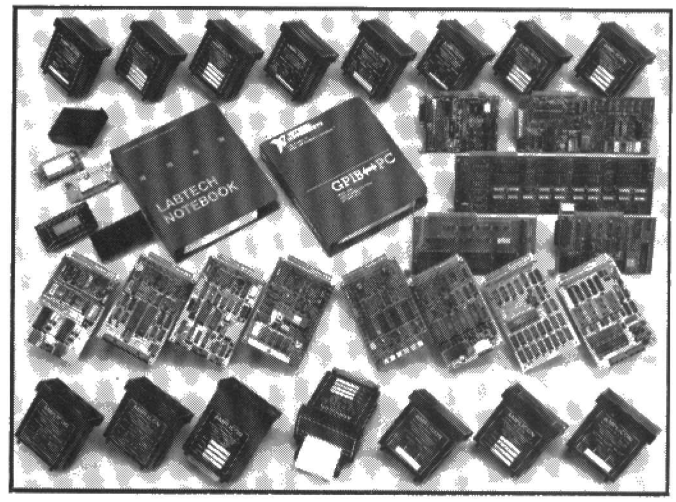
laboratories than all but the most dedicated of private students.

The built in regulated d.c. powe supply is fully short circuit protected, with ranges of +5V/1A, ±5V/0.5V, and 0 to ±15V/0.3A. The function generator provides 1Hz to 100kHz continously, variable over five decade ranges. The waveform outputs available peak to peak are 0 - ±5V sine wave, 0 - ±triangle wave and 0 - ±5V square wave. The digital voltmeter provides four ranges from 199.99mV to 199.99V Fsd. A pulse button generates a pulse of 10μs.

A thirty day evaluation period for the unit can be arranged with Flight Electronics. The FLT-102 looks like a very well designed and compact unit with considerable versatility for the money. As well as teaching establishments, businesses with small electronics workshops doing limited amounts of design and development, particularly in digital, may find the unit worth looking into.

Control By Phone

AMPLICON Liveline Ltd. is a new company within the Amplicon Electronics group, formed to market a family of industrial measurement, data acquisition and control instruments. The company believe that they are the first British electronics company to provide customers with a British Telecom Linkline number: customers anywhere in the UK can make a charge-free call on 0800 525 335 for direct access to the sales desk.

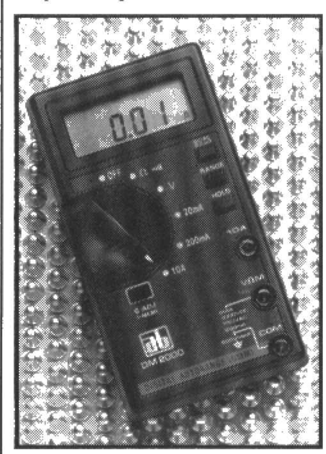


Liveline have their design, manufacturing and marketing facilities all on one site, and expect to be able to set a high standard of customer service, technical documentation and value. Direct keyboard entry on the sales desk, using an IBM System 36 computer, allows despatch orders to be produced quickly, so that stock orders received up to 5pm can be despatched the same day.

The company's main product lines are digital panel instrumentation (meters, counters, printers etc.), board level products for the IBN PC (D to a and A to D conversion, relays non volatile bubble memory, programmable TTL I/O, thermocouple amplification, logic analsyer, EPROM programmer) and STE bus (P1000) products (processor, memory, battery backed clock, disc controller a.d.c., OS9 operating system, parallel and serial I/O). The units allow users to specify economical systems for data acquisition and control from the very simple to the very complex.

Digital Meter

AB European Marketing have added the DM2000 digital multimeter to their instrument range. Costing around £31.95, excluding VAT and carriage, the meter handles current up to 10A in manual mode (below 10A the device is fused), and voltage to 1000V and resistance up to 2 megohms in auto and manual modes; audible and visual continuity check, diode test, hold function, and high/low impedance facility are featured. The meter comes complete with one metre test leads, a 9V battery and instructions. Case and croc clips are optional extras.



COUNTDOWN

If you are organising any electrical, computing, electronic, radio or scientific event, big or small, drop us a line. We shall be glad to include it here. Address details to COUNTDOWN, Practical Electronics, 16 Garway Road, Bayswater, London W2 4NH.

PLEASE NOTE: Some of the exhibitions and events mentioned here are trade only or may be restricted to certain categories of visitor. Also please check dates, times and any other relevant details with the organisers before setting out as we cannot guarantee the accuracy of the information presented here.

IEEIE – Wind Power, 11th March 7.30pm, White Horse Hotel, Dorking, Surrey. 01-836-3357.

IEEIE – Mobile Communications, 12th March 6.00pm, Lecture Room B15, Mountbatten Building, Meriott-Watt University, Grassmarket, Edinburgh. 01-836-3357.

IEEIE – Expert Systems, 19th March 6.30pm, Room 6.12, Queens University of Belfast. 01-868-3357.

Southcon '87, March 24th-26th, Atlanta, Georgia, USA. 0101-212-421-6816.

Cadcam '87, March 24th-26th, Metropole Hotel, National Exhibition Centre, Birmingham. 01-608-1161.

Internepcon Production Show and Conference, March 24th-26th, National Exhibition Centre, Birmingham. 0792-792792.

Electronic Printing and Publishing, March 24th-27th, Olympia, London. 01-647-1001.

IEEIE – Hotol, 26th March 8.00pm, Sir Alan Cobham Lounge, Terminal Buidling, Hurn Airport. 01-868-3357.

Drives '87 Seminar, 3rd April, Lincoln College of Technology. 0522-30641.

Components Fair, 5th April, Pontefract and District Amateur Radio Society, Carleton Community Centre, Carleton, Pontefract. 0977-43101.

Saturn Workshops, 6th-10th April, several residential computer courses, Ludgrove Hall, near Cockfosters tube station, London. 0969-50449.

Laboratory Manchester, 8th-9th April, New Century Hall, Manchester. 0799-26699.

IOA – Acoustics '87, 13th-16th April, Management Centre, Portsmouth Polytechnic. 031-225-2143.

Homvention '87, April 24th-26th, Dayton, Ohio, USA. 0101-603-878-1441.

Electronic Data Interchange Conference, April 28th-29th, The Baribcan Centre, London. 01-868-4466.

British Electronics Week '87, April 28th-30th, (incorporating All Electronics/ECIF show, Automatic Test Equipment, Circuit Technology, Communications), Olympia, London. 0799-26699.

I/O For PC

A series of multi-slots motherboard which will accept a range of standard I/O function cards, marketed by Electronic & Computer Workshop Ltd., is now available in an intelligent RS232 interfaced version for IBM PCs and compatibles.

Designated the K2612 for PCs, I/O system includes an eight channel analogue multiplexer, A to D and D to A conversion, a Centronics printer port, eight channel logic input, real time clock and a general purpose output card with a choice of relay and triac outputs.

Also included is a breadboard plug-in to allow more experimental users to develop their own interfacing projects.

No-Smoke Detector

PHOTAIN Controls Ltd. is marketing a new ionisation smoke detector which can detect 'fallout' from a fire before visible smoke is produced and before a discernable rise in temperature. Selling at £24.00 plus VAT, the unit, designated ISD-P, is compatible with most types of 24V d.c., two wire, normally open fire sensor loop circuits, and up to fifty detectors can be connected to each zone.

The smoke detector was designed, says Photain, for high stability and reliability without sacrificing sensitivity, with the aim of reducing false alarms while maintaining the detector's effectiveness. This was achieved

Books

William Heinemann have now published the fifth edition of the popular Newnes Electronics Pocket Book by E.A. Parr, priced £8.95. The pocket book, which 'covers all aspects of electronics in a highly readable and non-mathematical form' has been completely revised and updated, with a new chapter on computing, op-amp applications and digital circuit design. Communications and computing have a heavy emphasis in the new edition, which hopes to mirror the increasing emphasis on information technology in the electronics industries, work and (gradually) home environments. The information in the Newnes Electronics Pocket Book is of interest to amateurs, and provides a good ready reference book for professional engineers.

Taking up the theme of satellite television again, J. Vincent Technical Book have addedThe Ku-Band SatelliteTV, Theory Installation and Repair manual to its recently instituted list of publications for sat-TV enthusiasts.

The manual is said to be a comprehensive guide to the installation and adjustment of domestic satellite dishes, with clear and concise text and easy-to-understand illustrations. Also included is information on site surveying, cable television, the descrambling of satellite transmissions and tracking and establishing links with satellites around the world. The book is already on sale in the USA. The UK price is £23, including post and packing and it is also being sold through The Modern Book Shop in London.

by including a fully encased printed circuit which has a high level of protection against electrical interference and line transients. High level immunity to air currents has also been incorporated in the design.

The detector is available with a base to which other types of detectors can be connected without need for any wiring changes.

New optical network

British Telecom is currently working on a $50M optical fibre network linking up their customers in the City of London. This is the first stage in a major programme to install the most advanced type of single mode optical fibre into business communications, and BT are expecting to install more than 60,000km of fibre in the next twelve months – enought to go twice round the equator.

The advantage of the new system is that BT's customers will be able to send all their services through a single 'pipeline', with better transmission quality and greater flexibility than allowed by conventional cable communications. Telecom say that these installations into business premises are just part of a billion pound per annum project to update the telecommunications network fully. Modernisations of the trunk network is advanced. and £40,000,000 is budgetted for bringing in local digital exchanges this year.

Optical fibre cable is already standard for the trunk and junction networks, but is new to local networks and customer premises. The price of optical fibres is coming down, and they allow great flexibility in routing and altering services, especially where there is a large concentration of customer lines.

The current installation work is being carried on from Kings's Cross in the north to Elephant and Castle south of the Thames, and from Covent Garden just west of the City of London to Wapping in the east. Following this, the local fibre connections will be carried out to the rest of London, including the fast developing dockland sites, and the rest of Britain. Around 100 Dealerinterlink users will be the first to use the new network in spring 1987.

Dealerinterlink was set up by BT as part of their support for the Big Bang computerisation of the City. Customers rent groups of circuits connected to a central point. In this way private speech links can be set up with fellow members within 24 hours.

Other services planned include telex, packed switched data lines, private circuits, KiloStream and MegaStream. The optical fibre lines will be able to connect with the public telephone network.

In the local networks, Telecom will use fibres carrying transmission of 2M bits per second (the equivalent of 30 telephone channels) to 140M bits per second. The City network will start out with transmission rates of either 8M or 34M bits per second. The single mode fibre used provides virtually limitless bandwith for future services, which, it is hoped, will forestall the need for new cable installations.

Most of the hardware is being made in the UK by GEC, Plessey, BICC and TCL. Tenders for the next phase of the programme are now being considered.

Tasteful Insulators!

INSULATOR manufacturers Thermalloy have produced an electrical insulating material which is highly conductive to heat. Called Thermalsil, the material is composed of a silicone elastomer binder with a heat conductive filler, reinforced with glass cloth. The material is flexible and resists tearing or cutting by sharp edges or burns on adjacent components, but does not need thermal grease to effect the heat transfer. Two varieties are now being made available: Thermalsil II, which is .009in thick and blue grey, and Thermalsil III, which is .006in thick and green-grey. This, say Thermalloy, is 'the thinnest possible matrix for enhanced thermal resistance'. The material comes in standard semiconductor TO-package and washer shapes, and in rolls, with or without an adhesive backing, from MCP.

FIRM CONTACT

Addresses of this month's news items (excepting those which already have addresses included in the text) to be added to addresses of regular advertisers in FIRM CONTACT

Riscomp Ltd., 51 Poppy Road, Princes Risborough, Bucks HP17 9DB.

Camboard, Unit 16, Barnwell Business Park, Barnwell Road, Cambridge CB5 8UZ.

Lefax Ltd., Unit 6, Genesis Business Centre, Redkiln Way, Horsham, W. Sussex RH13 5QH.

Electronic & Computer Workshop Ltd., 171 Broomfield Road, Chelmsford, Essex CM1 1RY.

Audiokits Precision Components, 6 Mill Close, Borrowash, Derby DE7 3GU.

Flight Electronics Ltd., Ascupart St., Southampton SO1 1LU.

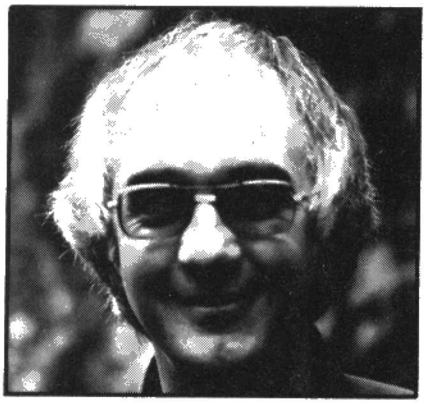
Amplicon Liveline Ltd., Centenary Industrial Estate, Brighton, E. Sussex BN2 4AW.

AB European Marketing, Wharfdale Road, Pentwyn, Cardiff CF2 7HB.

J. Vincent Technical Books, 24 River Gardens, Purley, Reading RG8 8BX. Tel. (0734) 414468.

William Heinemann Ltd., 10 Upper Grosvenor Street, London W1X 9PA.

MCP Electronics Ltd., 26-32 Rosemont Road, Alperton, Wembley, Middx. HA0 4QY.



THE LEADING EDGE

BY BARRY FOX

The vice-president of Texas Instruments predicts a complete change of approach in i.c. architecture in the next decade.

Texas Instruments was in at the beginning of the transistor age, marketing the first silicon device in 1954. Over recent years Texas has pulled out of the cut-throat market for low cost computers and taken a hammering from the Japanese. Now Texas says it will beat the Japanese electronics industry to the market with a 4 megabit memory chip.

George Heilmeier, who is vice-president of TI and in charge of all its research and development, was in London recently and put the last thirty years in perspective. Heilmeier's remarks came soon after a speech by Alec Broers, Professor of Electrical Engineering at Cambridge University. Broers said Britain was several years behind the US and Japan in chip technology and that the UK should get out of chip manufacture and concentrate on state-of-the-art research and design.

Since 1959, when the first integrated circuits were made, the size of individual components on the chip – or 'feature size' – has reduced by 11% per year. There is now a hundredfold increase per decade in the number of devices which can be crammed into a square centimetre chip area. "If the same thing had happened with cars" says Heilmeier "a Rolls Royce would now cost $3, run 3 million miles on a gallon, have the power of the QE2 and be so small that you could get six on the head of a pin".

Heilmeier believes that chip development has now reached a crucial stage. There is no point in simply continuing to put smaller devices closer together on a single chip. Since the turn of the 80 s the industry has been ruling circuit lines on chips with a spacing of less than one micrometre or micron.

"That has separated the men from the boys" he says "Now we have different problems. The connections between the devices dictate the speed of operation. The time taken by the electrons to move round the chip becomes a significant factor. So does interference and interaction between individual parts of the circuit".

"There is no fundamental physical barrier to making conventional chips with a line spacing of less than 0.1 micron. You can work down to around 0.6 microns with ultraviolet light and photo lithography. Below that you have to use electron beams. We can go to 0.1 microns lines spacing in the laboratory – but frankly it's just not interesting because the isolation and interconnect problems become too real".

"For solid state devices the real limit will in practice be between 0.3 and 0.5 microns. If the limits of the device don't get you, the limits at system level will. Something is going to have to happen to push the industry beyond the 0.3 micrometre barrier".

"When? Probably post 1995".

Echoing Professor Broers' remarks (which were given, incidentally, to academics at a Texas Open Day in the UK earlier in the year) Heilmeier warns:

"It is becoming increasingly difficult for small companies to operate in this business. They can design architecture and write software but not manufacture the chips".

The search is now on for new ways of using silicon, and new materials to use instead of silicon. Today's state of the art is a 1 megabit D-RAM (dynamic random access memory) with 1 micron circuit lines. Most of the large Japanese electronics companies say they too have developed 4 Mbit DRAMs. Texas claims a lead with prototype 4 megabit DRAMs made with a 3-dimensional CMOS technique. The chip devices, capacitors and transistors, are sunk into a trench in the silicon and stood upright. This improves isolation and increases packing density. The 4 Mbit D-RAM has 8.4 million components on a 1 square centimetre chip, with 1 micron line spacing.

Heilmeier believes that gallium arsenide material is the best bet for the future. Electrons move much faster through it than silicon. The snag is that GaAs is expensive, brittle and very difficult to work with. TI is now experimenting with devices (1K SRAM) made from hybrid material, a thin layer of gallium arsenide grown on a silicon base.

Why bother with such a low capacity device? "They are blindingly fast" says Heilmeier. "Also GaAs uses much less power than silicon. but you only have to look at it and it shatters.

Heilmeier is not very enthusiastic about today's vox pop talk of biochips, made from materials like chlorophyll.

"Biological materials never make good transistors, they are too slow. But there is the advantage that individual defects on the chip don't matter. Storage in non-localized".

Biochips work like a hologram – if one piece of the memory is missing, the rest of the memory still holds the same information.

"But remember", adds Heilmeir "that for memory devices, moving optical media – like compact disc – offer much higher density than solid state systems".

Heilmeir has the answer to the obvious question – what are we going to do with all this computing and memory power?

"We need it for the interface between humans and computers. The research team at Xerox who started off trying to make computers more friendly were handicapped because they were too early. There wasn't the technology available at the right price. Companies like Apple made the Mac. Software is now the limiting factor".

"For speech understanding or image understanding you need a very powerful interface - for instance to use a camera and computer to recognise an object in an environment, irrespective of its position. In a browsing database we want to be able to tell the system what to do, not have to tell it how to do it. Vision technology is just aching for parallel processing. Physically stitching many processers together is the easy part. but it's not enough. It's like putting many people on the same project – it takes time for them to communicate with each other. The key is breaking down the problem into the many parts that can be solved by parallel processing and the few parts that need serial processing. You need to extract the parallelism from the problem".

Obviously the Japanese think the same way. Matsushita recently announced the "world's fastest realtime image processor", it is an image sensor that can be paralleled to give a robot sight. PE

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ELECTRONICS IS FASCINATING

REGULAR readers will be aware of my longstanding association with PE and of my enthusiasm for all matters electronic, which has I hope, been reflected in my constructional articles. My new appointment to the Editorial chair now offers even wider scope for my endeavours to encourage you all to share this enthusiasm.

From an initial childhood interest sparked off by finding that fuses could be blown, curiosity in electronics was further developed through messing around with old television sets, often bought from junk heaps for the sake of the parts. During several years as a film editor, the hobby grew into an acute passion, and every electronics magazine available was hastily acquired. I remember my pleasure when reading the first issue of PE – those pages were bliss to me, opening up new areas of previously uncharted experimentation. Eventually it was inescapable that I should turn professional and I began by contributing my own constructional projects to PE. The encouragement I was shown by Fred Bennett and Mike Kenward in their days as editors of PE was invaluable.

Through the expertise and understanding of its editors, PE has established a long tradition of excellent constructional projects and informative articles. These reflect all aspects of electronics and associated disciplines, with special emphasis on technological trends, and the importance of education in implementing them. I shall maintain this tradition, and broaden its horizons.

Much of modern technology heavily depends on computer circuitry in its various forms. In common with other authors, I have recently been showing in my projects how computers can be used for far more than just playing games. Many more readers are now aware of the benefits and satisfaction of combining their interest in computers with that of electronics. Construction of all types of electronic projects, both digital and analogue, is once again dominating hobby workrooms. PE is devoted to encouraging and educating you in this reviving interest, and will continue to publish authoritative articles suited to your level of electronic ability, whether you are involved in professional electronics, technological education, or simply an enthusiastic amateur who, like myself many years ago, craves for more knowledge.

For me, electronics is fascinating, instructional, and vital to the society in which we live. There can be few areas left in which it is not making its impact felt. Inevitably, many more aspects of life will become changed by further innovations. Ensuring that such advances are both possible and beneficial, requires knowledge, understanding and acceptance by not just experts, but also those whom the changes affect most. Through electronics and the pages of PE, you too can learn about and experience today's essential technology as it shapes tomorrow's world now – and it's fun.

THE EDITOR

OUR MAY 1987 ISSUE WILL BE ON SALE FRIDAY, APRIL 3rd 1987 (see page 31)

EXPERIMENTAL ELECTRONICS

BY THE PROF

Inductive loop transmission

Inductive loop systems have some valuable practical applications, such as, for example, large scale hearing aid transmitters in public places. The Prof peruses the principles.

INDUCTIVE loop transmission and reception is one of those things I have been meaning to try out for quite some time (about 20 years), but I have only just got around ot it now. I do not know and have not been able to trace the history of this method of communication, but it almost certainly dates back to the very early days of electronics, and is not something that requires any high technology components in order to produce a working system. In fact it is basically just two amplifiers and two coils of wire.

It has to be pointed out straight away that we are not talking about a communications system of the radio or intercom type, but more something to enable signals to be picked up anywhere within a room. A system of this type may seem to be of little or no practical value, but it does have practical applications. The obvious use is as the basis of a "cordless" headphone system, where electronics mounted on the headphones pick up the signal radiated by the transmitter, and the user is free from any direct connection to the radio, televison, or other signal source. This is essentially the same idea as the infra-red style cordless headphones which have been around for many years now, but it is potentially a much cheaper and easier system to implement. On the other hand, it perhaps offers a level of performance that is slightly less good in some respects than that of a good infra-red system, and it is somewhat more difficult to install. Which system is the most suitable therefore depends on the exact circumstances under which the system will be used, and on the level of performance required. For the present we will not consider the infra-red system further, but as far as the electronics are concerned it is basically the same as the infra-red communicator featured in the first article in this series. This is a topic to which we may well return in a future article.

Although any system of this general type may seem to be a gimmick and an unnecessary expense rather than a genuinely worthwhile proposition, anyone who has used headphones extensively will probably immediately appreciate the convenience of cordless headphones. In particular, it avoids the nearly neck breaking experience of getting up from a chair while standing on the headphone lead, or when walking around wearing headphones, literally reaching the end of ones tether.

Although I have no first hand knowledge of modern hearing aids, apparently many modern types can be switched from the normal microphone source to an inductive pick-up. The pick-up is primarily intended for use with telephones in much the same way as the telephone pick-up coils used with telephone amplifiers, but they can also be used in halls, cinemas, etc. which have a suitable transmission system.

LOOPING THE LOOP

When dealing with a subject of this type it is very easy to get embroiled in pages of mathematics, but the system consists of what is really just an enormous and inefficient transformer with amplifiers at the input and output to overcome the losses. The block diagram of Fig. 1 outlines the requirements for a practical inductive loop communications system.

The transmitter is just an audio power amplifier feeding the transmission loop. The latter is just a loop of wire around the periphery of the room in which the system is to function, and it can consist of just a single turn. However, the strength of the magnetic field within the loop is dependent upon the current in the coil and the number of turns in the transmission coil. In order to produce a strong field it is therefore necessary either to have a very high current of a few amps in the coil, or to have several turns.

In practice an ordinary power amplifier can produce quite a high output current and give a fairly strong field with a single turn, but the impedance of such a transmission loop is likely to be far

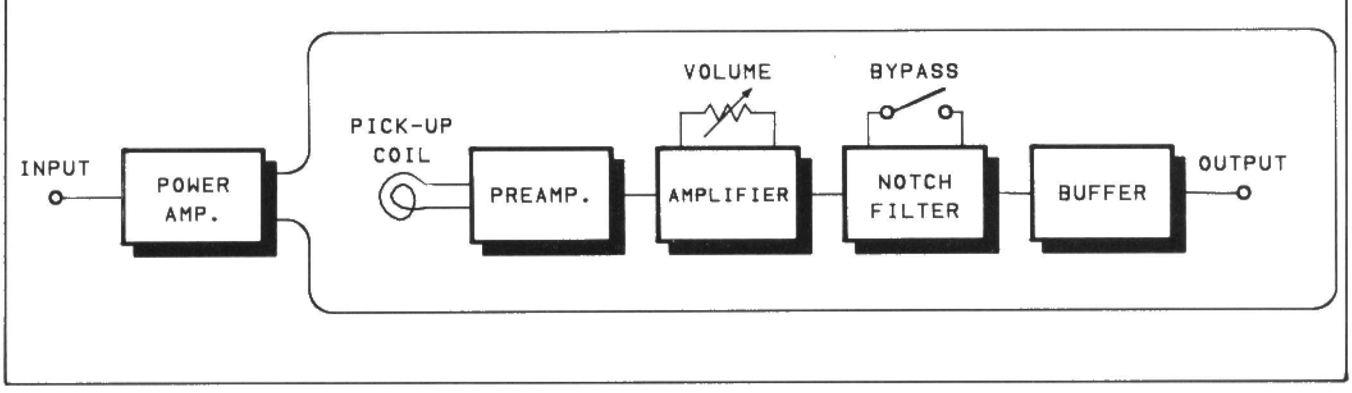


Fig.1. *Block diagram for a practical inductive loop system.*

lower than that of a standard 8 ohm impedance loudspeaker. This obviously depends on factors such as the length of the wire in the loop and its resistance, but unless the system is fitted to a very large room, the impedance of a single turn loop is likely to be less than a couple of ohms. In order to get good efficiency from the system it is therefore necessary either to feed the transmission loop via a step-down transformer, or to use more turns in order to give the coil a higher impedance. On the face of it the step-down transformer is the easier way of doing things, but a suitable ready-made component would almost certainly be impossible to obtain. A transformer could also result in some loss of performance, particularly in terms of frequency response and distortion. The extra effort needed to add a few additional turns onto the transmission coil is therefore probably the easier and better alternative.

A pick-up coil is needed at the receiver, and even a small air-spaced coil having just a few turns seems to give a reasonable amount of pick up. Not surprisingly though, of the various inductors that I tried a telephone pick-up coil gave by far the best results. The output from the coil is not likely to be very great, and when used with a telephone the output level would typically be around 500 microvolts r.m.s. In this application a higher output level can be obtained from the coil. The output level is still likely to be a matter of a few millivolts r.m.s., and a preamplifier is used to boost it to a higher level before any signal processing is undertaken. In fact two stages of amplification are used, with a volume control being included in this part of the unit.

This signal processing simply consists of a 50 Hertz notch filter which can be switched into circuit if desired. The main problem with an inductive loop communications system is that the pick-up coil will respond to any magnetic field which has audio frequency modulation, and not just to the field radiated by the transmitter. There are few likely sources of such fields, but the main one that has to be contended with, and which can generate quite a strong field, is the mains wiring. The 50 Hertz notch filter will severely attenuate any mains "hum", but it is not a total solution to the problem. One obvious drawback of using the filter is that it gives a loss of wanted bass signals as well as the unwanted mains "hum". Also it only attenuates the 50 Hertz fundamental signal, and has little effect on 100 Hertz and higher harmonics, which are likely to be present at lower but still quite significant strengths.

The 50 Hertz notch filter is a useful addition to the unit, but it should be regarded as a last resort, and other means of combating mains interference

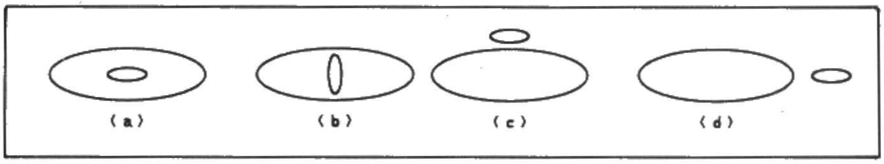


Fig.2. *Relative transmission and pick-up coil orientations. (a) gives optimum pick-up, (b) gives minimum, (c) gives slightly less than maximum and (d) provides little output signal.*

should be used where possible. The main way of reducing the "hum" to an insignificant level is to strive for the highest possible field strength from the transmitter. This enables the gain of the receiver to be kept well backed-off, and any background noise ("hum" or otherwise) to be effectively reduced.

Another method which can be used to good effect is to utilise the directivity of the pick-up coil. Fig.2 helps to explain the way in which this functions. In Fig.2(a) the transmission loop and pick-up coil are properly aligned and in the same plain, and this gives maximum output from the pick-up coil. The field strength is not uniform within the area enclosed by the transmission coil, but it varies by less than one would probably expect. The volume seems to remain virtually constant within the area coverred by the unit, although it does become very much stronger if the pick-up coil is placed within about 300 millimetres or so of any part of the transmission coil.

Minimum pick-up is obtained with the pick-up rotated through 90 degrees, as in Fig.2(b). In fact, if the pick-up coil is rotated carefully, it can usually be set to completely null the signal from the transmitter. In the same way, the coil can be rotated to null the signal from a source of interference, and with luck it will be possible to find an orientation that gives good pick-up of the wanted signal while totally eliminating any interference. This is analogous to rotating a medium wave radio receiver that has a ferrite rod aerial to null an interfering signal.

While on the subject of relative field strengths, it is worth pointing out that the field is strongest within the transmission loop. Moving the coil upwards, as in Fig.2(c), (or downwards of course), results in a reduction in the strength of the received signal. This should be borne in mind when installing the transmission coil, as it should ideally be at about the same height as the receiver unit will be in normal use, which is probably about one metre above floor level. In practice this might be difficult, and the coil may have to be fitted at floor or almost ceiling height. This should still give a strong signal at the receiver, but any mains "hum" or other interference will be that much more prominent.

If the loop is taken outside the transmission loop, as in Fig.2(d), the strength of the received signal seems to rapidly diminish as the receiver is moved away from the coil. The practical result of this is that it is unlikely that satisfactory results will be obtained if the receiver is used in one room when the transmission loop is installed in the next room. Either the loop must embrace both rooms, or each room must have its own inductive loop transmitter system.

Returning now to the block diagram of Fig.1, the output from the notch filter is fed to a buffer amplifier. This is needed to give an output that is capable of driving most types of headphone or earpiece.

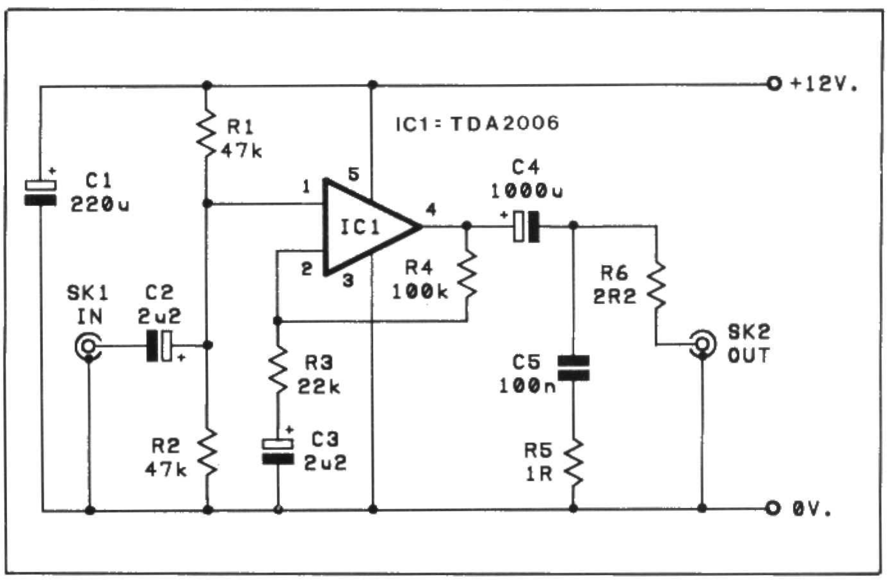


Fig.3. *The transmitter circuit diagram.*

TRANSMITTER CIRCUIT

Virtually any small power amplifier can be used to drive the transmission loop, but ideally the amplifier should be a type which is stable and has overload protection circuits, as the output loading is something of an unknown quantity. An amplifier that is fussy about the output loading could well give problems with instability, and a type which lacks any output overload protection could well be damaged if the impedance of the transmission loop proved to be somewhat too low.

I used the circuit shown in Fig.3, and this proved to give very good results. It is based on the TDA2006 audio power amplifier chip, which is rather like a high power operational amplifier. The device has the standard operational amplifier style inverting and non-inverting inputs, but unlike many audio power amplifiers, it does not include any internal biasing or feedback resistors. This device is more stable than most audio power amplifier integrated circuits (and discrete designs), and it has comprehensive output overload and thermal protection circuits.

It is operated here in what is just the ordinary non-inverting mode amplifier circuit, but as a single supply rail is used, R1 and R2 are needed to bias the non-inverting input. R3 and R4 set the voltage gain at about 5.5 times, which should be adequate for most signal sources, but the gain can easily be boosted if necessary, by increasing the value of R4. C5 and R5 are the usual C-R network used at the output of amplifiers to give improved stability, and they are the only compensation components that are needed in this case.

R6 ensures that the output of the amplifier is feeding into a reasonable load impedance. If the transmission loop provides a reasonably high input impedance (which in this context means around 4 ohms or more), R6 serves no useful purpose and can be replaced with a shorting link. If the input impedance of the transmission loop is too low, R6 ensures that the amplifier is feeding into a high enough load impedance for it to give good performance. R6 is not needed in order to prevent damage to IC1, but to ensure that it can operate under favourable conditions so that good distortion performance is obtained. In order to get really good results from the system, the transmission coil should provide a suitable load impedance so that the losses caused by R6 are avoided, and the output signal of IC1 is efficiently coupled into the coil.

IC1 requires a minimum supply voltage of 12 volts, although the TDA2006s I tried seemed to work quite well down to 9 volts. There is no point in using a higher supply voltage, except in the unlikely event that the impedance of the transmission coil is so high that a higher supply voltage is needed, in order to drive it with a high current. IC1 has a class B output stage, and although the quiescent current consumption will only be about 40 milliamps, at high output levels the current consumption can be several hundred milliamps.

RECEIVER CIRCUIT

The receiver circuit diagram appears in Fig.4. The pick-up coil connects to SK1, and from here the signal is coupled to the input of a high gain common emitter amplifier built around TR1. From here the signal is taken via volume control VR1 to a second high gain common emitter stage, this time based on TR2. C6 to C8, and R6 to R8 form a conventional twin T notch filter having an operating frequency of about 50 Hertz, and S1 is the bypass switch. IC1 is the output buffer stage, and this is just a 741C operational amplifier connected as a voltage follower.

The current consumption of the unit is only about 4 milliamps or so, and the unit can be powered from a small (PP3 size) 9 volt battery. The output is suitable for high or medium impedance headphones, including the type sold as replacements for use with personal stereo units. With low and medium impedance types the two phones should be used with series connection, but with high impedance types parallel connection will probably furnish greater volume. With some low and medium impedance types it may be found that great care has to be taken with the setting of the volume control in order to avoid an excessive output level. With headphones of this type it is preferable to add a resistor of about 47 ohms in series with the output to provide a certain amount of attenuation. The unit will also drive a crystal earphone at good volume, but it will not drive low impedance magnetic types very well, or any type of headphone that is intended to be driven direct from loudspeaker outputs.

PRACTICALITIES

Probably many readers will already have suitable amplifiers for experimenting with inductive loop systems, but for those who do not, or would prefer to use the designs described here anyway, printed circuit designs for the transmitter and receiver are shown in Figs.5 and 6 respectively. Both boards are very straightforward and require little amplification. One point that has to be made is that IC1 in the transmitter will almost certainly require a heatsink if overheating and thermal shut-down are to be avoided. The amount of heatsinking required depends on the load impedance and on how hard the unit is driven, but for most purposes a small finned heatsink of the bolt-on variety will suffice.

For the transmission loop I used 24 s.w.g. enamelled copper wire, and for test purposes the system was rigged up in a room having approximate dimensions of 5 metres by 4 metres. Originally I used just a single turn on the coil, but this was later augmented to 4 turns, which seemed to give a better load impedance for the amplifier and a much stronger field. For this application some form of single strand insulated wire is probably more convenient than a multistrand type, as single core wires are more easily formed into a desired shape. Do not worry about making the coil round – perfectly good results will be obtained

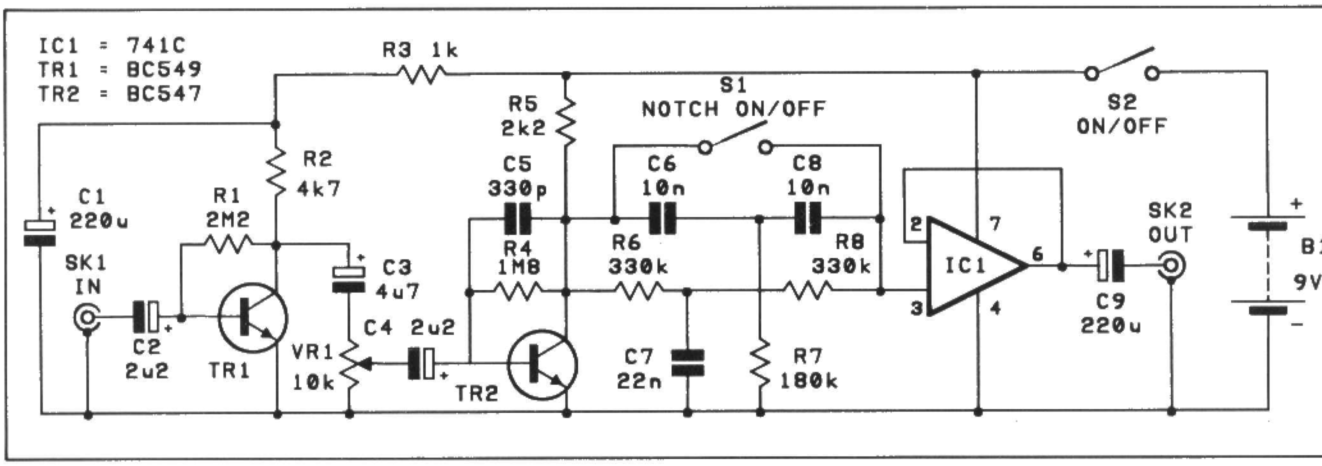


Fig.4. *The receiver circuit diagram.*

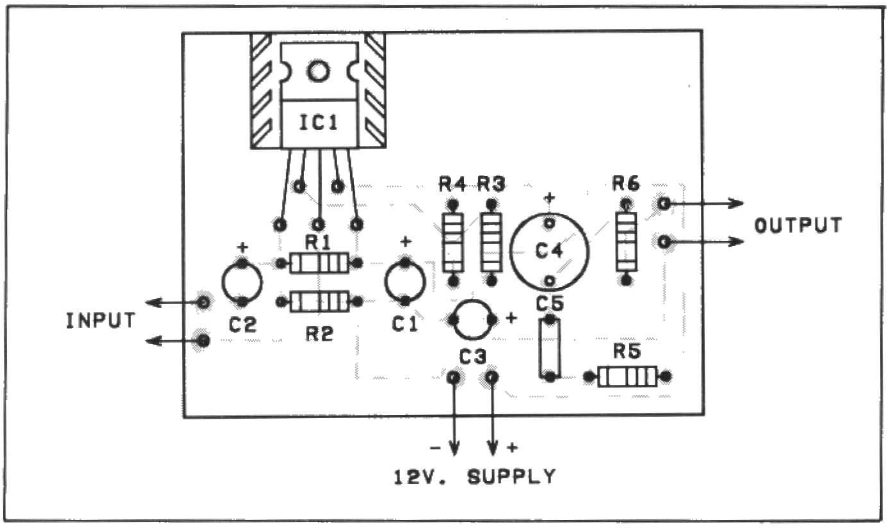


Fig.5. *Details of the transmitter board.*

COMPONENTS . . . TRANSMITTER

RESISTORS

R1,R2	47k (2 off)
R3	22k
R4	100k
R5	1R
R6	2R2 ½ watt

All ¼ watt 5% carbon unless noted

CAPACITORS

C1	220μ 16V radial elect
C2,C3	2μ2 50V radial elect (2 off)
C4	1000μ 16V radial elect
C5	130n polyester

SEMICONDUCTOR

IC1	TDA2006

MISCELLANEOUS

SK1,SK2	Standard jacks (2 off)

Printed circuit board, wire for loop, heatsink for IC1, solder, etc.

with a rectangular coil, or practically any shape come to that. It is not even necessary to have the entire winding at the same height, and taking the wire up and around a door frame for example, does not seem to have any great effect on the level of performance. However, as explained previously, for optimum results the coil should be at about the same height as the receiver will be in normal use. The exact guage of wire used is not too critical, but a very heavy gauge could give a rather low load impedance for the amplifier with consequent inefficient signal coupling. It could also be awkward from the installation point of view, while a very light gauge could be unable to handle the fairly high currents involved here, and could burn out. 24 s.w.g. wire offers a good compromise between these two extremes.

The pick-up coil can be left separate from the main receiver circuit and connected to the unit via SK1, or the latter can be omitted and the coil can then be mounted inside the case. If the pick-up coil is mounted in the case, keep in mind that optimum signal strength is obtained with the rubber suction cup facing either upwards or downwards.

If the unit is functioning properly there should be no shortage of volume from the receiver, and the audio quality should be quite good, if rather lacking in bass when the notch filter is switched into circuit. The input signal to the transmitter must be adjusted for optimum results, and this simply means setting the highest volume level that does not result in overloading and serious distortion. It is assumed here that the signal source has a volume control which can be used to set the input level to the unit, but if necessary a 10k logarithmic potentiometer can be wired volume control style at the input of the transmitter. The unit should not be fed direct from any piece of equipment that has a live chassis, except where this equipment has a properly isolated output, such as an earphone or tape socket, that can be safely used as signal take off point for the unit.

The receiver unit could be made quite small if necessary, and it would be quite feasible to build it onto a pair of headphones, although many modern types are of the ultra-lightweight type and it could be quite difficult with these. With a little ingenuity though, it should be possible to produce a bona fide pair of cordless headphones with a useful level of performance.

IMPROVEMENTS

For such a simple system, results seem remarkably good, but they are not so good that there is no room for improvement. How much mains "hum" is received depends on the conditions under which the system is used, but there will normally be a low but significant

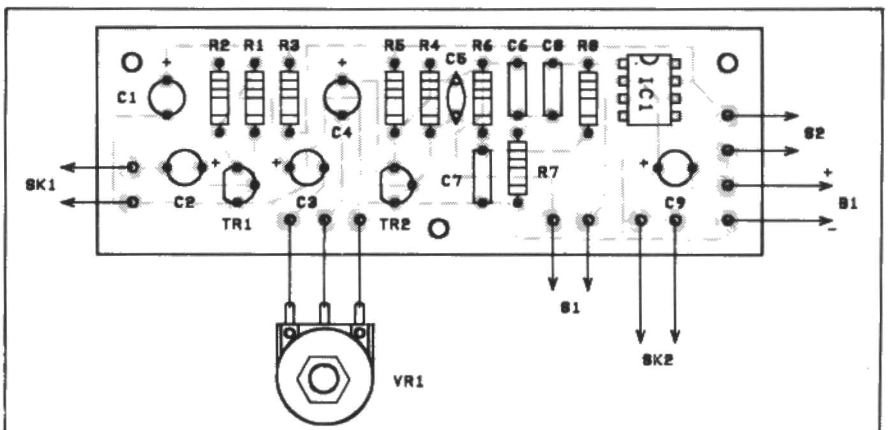
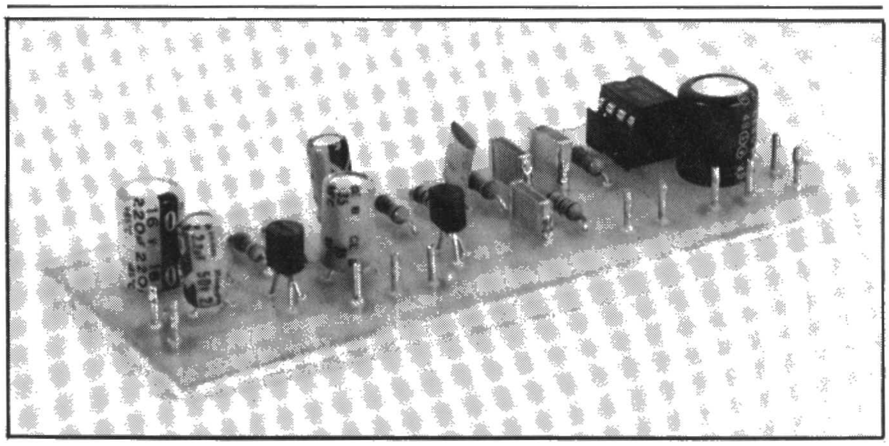


Fig.6. *Details of the Receiver Board.*



COMPONENTS . . . RECEIVER

RESISTORS

R1	2M2
R2	4k7
R3	1k
R4	1M8
R5	2k2
R6, R8	330k (2 off)
R7	180k

All ¼ watt 5% carbon

POTENTIOMETER

VR1	10k log

CAPACITORS

C1,C9	220μ 10V radial elect (2 off)
C2,C4	2μ2 50V radial elect (2 off)
C3	4μ7 50V radial elect
C5	330p ceramic plate
C6,C8	10n polyester (2 off)
C7	22n polyester

SEMICONDUCTORS

IC1	741C
TR1	BC549
TR2	BC547

MISCELLANEOUS

S1,S2	sub-min toggle (2 off)
SK1,SK2	3.5mm jacks (2 off)
B1	9 volt (PP3 size)

Printed circuit board, battery clip, 8 pin DIL i.c. holder, telephone pick-up coil, control knob, wire, solder, etc.

"hum" level. Increasing the field strength of the transmitter is the most effective way of counteracting sources of interference, and it is worthwhile experimenting with the number of turns in the transmission loop, in order to optimise the field strength. There is a limit to the field strength that can be obtained without resorting to very high transmitter powers, and a very strong field could give a few problems. In particular, there is a possibility of feedback to the signal source, and of interference being caused to nearby radio receivers, record players, etc. What should be a very effective way of combating mains interference is to use a comb filter having a series of very narrow notches at frequencies of 50, 100, 150, 200 Hertz, etc. Provided the filter could be tuned accurately it would give a high degree of attenuation to the frequencies in the interference, but if the notches were narrow enough there would be surprisingly little effect on the audio output quality.

Perhaps the most obvious improvement would be to try to implement a stereo system. One way of doing this would be to have an ultrasonic carrier wave to carry the information needed for the additional channel, using a system of the same general type as that utilised in stereo FM radio transmissions. This could potentialy cause radio interference and could be illegal, although there should be no problems if the carrier wave was kept at a relatively low level. On the face of it, if wireless intercoms are legal, then this system should be as well (but I have not checked with the authorities and can not guarantee this to be the case). There could be advantages to having both channels frequency modulated onto ultrasonic carrier waves. This would enable lower transmission powers to be used, and should give complete freedom from mains interference.

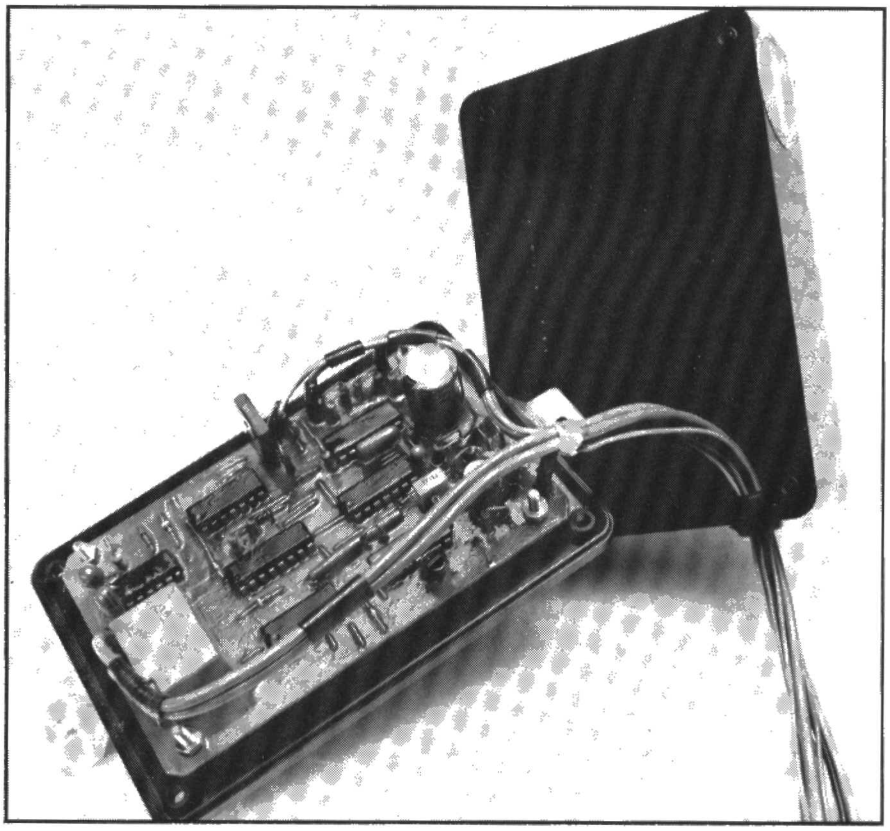
Another possible approach to stereo operation would be to have two transmission coils at right angles to one another (i.e. one around the four walls and the other around two walls, the floor, and the ceiling). With the two pick-up coils similarly orientated it should be possible to obtain sufficient channel separation for a good stereo image. However, while simple on paper this system could be practically impossible to implement in practice. PE

P.E. "VIGILANTE" CAR ALARM

BY MIKE DELANEY

Cars attract burglars. The Vigilante repells them

This is a concealed alarm which can employ either the car horn or a separate sounder as the siren, and is operated via the car's courtesy light and ignition system.



IT IS a sad relection of our times that it should be necessary to publish an article such as "Vigilante", but the facts speak for themselves. Car theft is an ever-increasing problem, to such an extent that the manufacturers have been forced to improve the quality of the locks they fit. This is fine for anyone buying one of the newer models with these fitted, but not all of us can afford a new car, and there's still a few miles left in my old model ...

It is important to realise at the outset that any alarm fitted to a vehicle is at best only a deterrent. The pro. car thief will get round most devices in a few seconds, or at best, a few minutes, but hopefully the joyrider, or late-night traveller, will be put off sufficiently to look for an easier target. If the alarm achieves this, it has done its job. But then, you'd never know it!

Incorporated in the Vigilante design are a couple of extra options to make life a bit easier for the owner. If you have ever left the lights on when parking on a foggy morning, to return after a day's work to the inevitable flat battery, then you will be pleased with one of the options. By taking a wire to the light switch it will signal when this line is high and the alarm is set.

The second is a circuit to hold on the courtesy light for a pre-determined period, or until the alarm is disabled. Many alarm systems presently on the market require the car owner to carry round a special key to enable and disable the alarm. This has been designed out in the case of the Vigilante. Although, if you wish, it is possible to fit another key-operated switch, the system may be operated through the vehicle ignition switch. Which method you choose depends upon how highly you rate the security offered by your vehicle keys. In many cases this is not too high!

Another, though not often used, option is for the system to be automatic. Each time the ignition is switched off the alarm sets itself. Useful for deliverymen, but not for the average driver.

The output drive is a relay closure, so this can be used to power the vehicle horn, or an external piezo sounder. Quiescent current drain is very low, in the order of 4mA, so there is no ON/OFF switch; any car battery which cannot stand this drain would be quite unable to start an engine.

In order to comply with local bye-laws the unit resets itself after the alarm period, and allows an enter/exit period, with audible warning each time a door is opened. There are several ways of detecting an intruder in a vehicle. Some are better than others, but each requires that the owner drill at least one hole in his pride of joy. The Vigilante, by monitoring the voltage level within the car, reduces the number of external connections, and in the case of the author's car, required only one small hole to accept the 'set' switch.

Throughout the whole design the external state of the car wiring and switching is taken as shown in Fig.4., and if your vehicle does not conform to this you will need to do some interfacing of your own.

BLOCK DIAGRAM

The block diagram is shown in Fig.1. ON/OFF control of the circuit is achieved bby the Enable flip flop. A Set switch turns the circuit on, and the car ignition switch turns it off.

When in the off condition, the Alert, Exit and Bark flip flops are all held in reset. Operating the Set switch flips over the Alert, and enables these three bistables. When the alarm is first set, the Exit flip flop is in its operate mode, and this toggles the Alert flip flop. The output from Alert goes high, turning on the interior light and the warning oscillator,

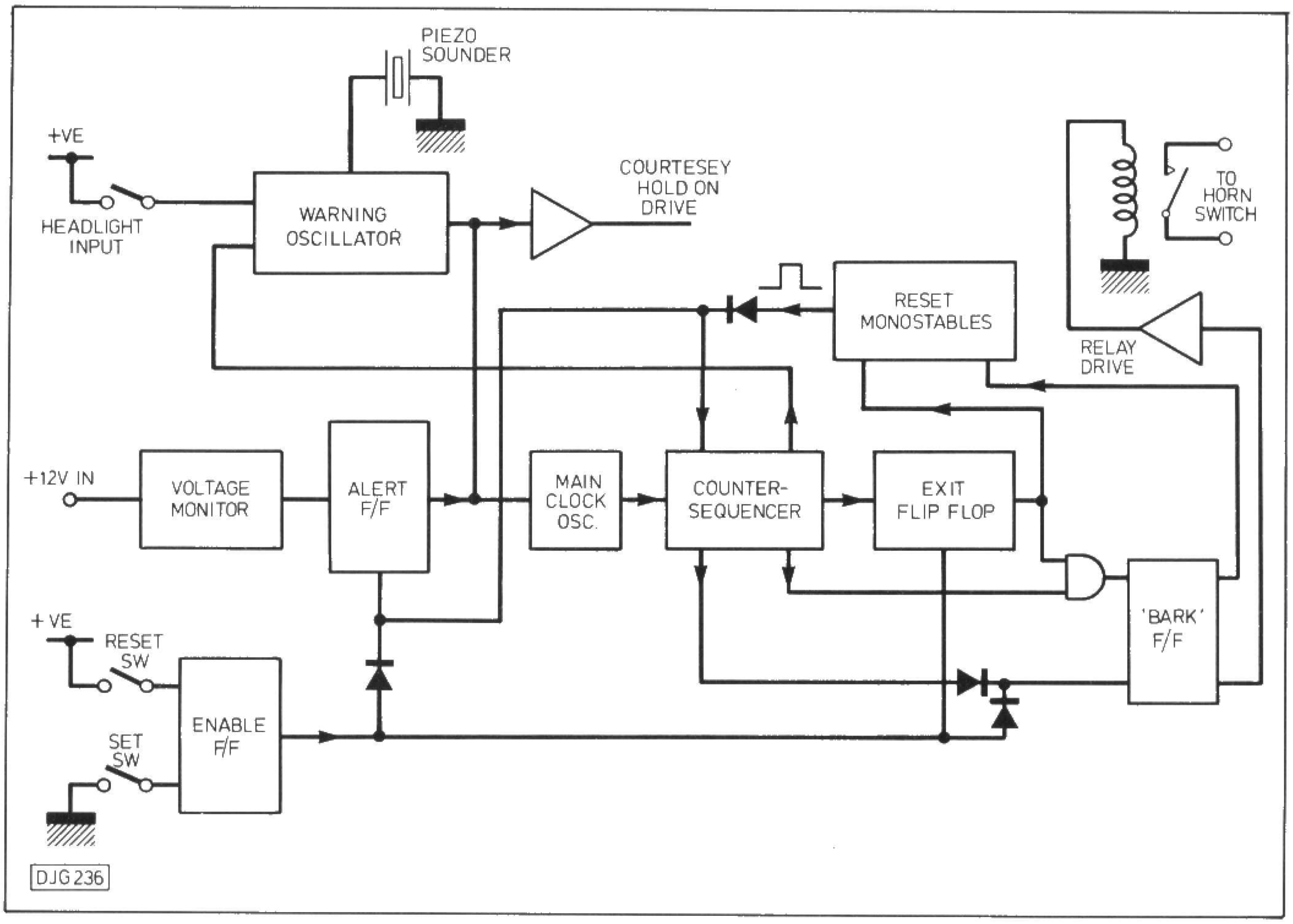


Fig.1. *Block diagram of PE Vigilante car alarm*

and starting the main clock oscillator. The counter/sequencer starts to count up from Ø, and after the predetermined period outputs a high to the Exit flip flop. This high toggles Exit, putting a high to the monostable, resetting the Alert flip flop, and setting the counter to Ø count.

By ANDing the Exit output to the Bark, the circuit is prevented from sounding the alarm followinng the first exit period. The monostable quickly returns to its stable (LOW) condition, enabling the Alert and counter as before, and the circuit is now in its alert condition. The voltage monitor is constantly sampling the supply voltage stored on a capacitor on one of its inputs. When the 'live' voltage suddenly drops, in the space of a few milliseconds and a few hundreds of millivolts, the monitor sees the unbalance and toggles the Alert flip flop as before.

This time, since the Exit flip flop has been toggled to its active state when the alarm was first set, when the counter reaches the end of the Exit period, the Bark flip flop toggles, sounding the alarm. Following the alarm period, the counter puts a high onto the reset pin of the Bark flip flop, resetting it to the alert state, which in turn triggers the Reset mono, resetting the counter and Alert as before. The circuit returns to its stable, Alert state, awaiting further triggers to the monitor.

Part of the warning oscillator is also monitoring the input from the lighting circuit in the car. When the warning is active, and the input from the light circuit is high, that is when the lights are on, the oscillator is gated such that the continuous tone becomes intermittent, signalling the lighting status. Of course, the fact that the lights are on will not affect the operation of the alarm.

THE CIRCUIT

The two system switches are the Set (S1), and Reset (S2) switches, and these are taken to the Enable flip flop, IC2b, half of a 4013.

The switches are isolated from direct connection by 1k resistors, to limit current into the i.c.s. in case of gross chip failure. The Set switch is buffered, and inverted by IC4b, before its output is taken to the flip flop. The reason for this arrangement is to allow the wiring to S1 to be as simple as possible when installing. It is only necessary to run one wire from the alarm to the switch, the other side of which can be connected, locally, direct to chassis. By arranging the two inputs as shown, the logic on the output is such that the ONLY time the output on pinn 12 will be low will be when the input to pin 10 is low, and the input to pin 8 is taken high. This arrangement ensures that no matter what might be done to the Set switch, it can only *arm* the circuit, and only the Reset (ignition) switch can turn the system off. Also, the circuit can only be set when the ignition is off.

When turned off the output on pin 12 of IC2 is high. This levels holds Alert, IC2a and the counter in reset via D4, Exit via pin 10, and bark, IC7a through D7. IC3d inverts the level, and blocks the output from gate 6b, putting a low level onto the S input of the Alert flip flop, pin 6. When the alarm is set pin 12, IC2b goes low, enabling the three flip flops, and the counter. The output of gate 3d goes high, and since the logic output from the Exit flip flop, pin 12 is high, gate 6b's output also goes high.

This high level on pin 6 of IC2a sets the Q output high, and this enables the clock comprising gate 3c, C3 and R12. At the same time TR1 is turned hard on via R10, turning on the interior light, and D5 is reverse biased, which allows the warning oscillator to start up.

In the event of the lighting circuit being active, the input on pin 8 of gate 4c will be high. Divided-down pulses are taken from the counter chip, IC5, a 4020, fed to the other input pin 9, of gate 4c, inverted, and then fed to the warning oscillator gate, 4d on pin 12. In

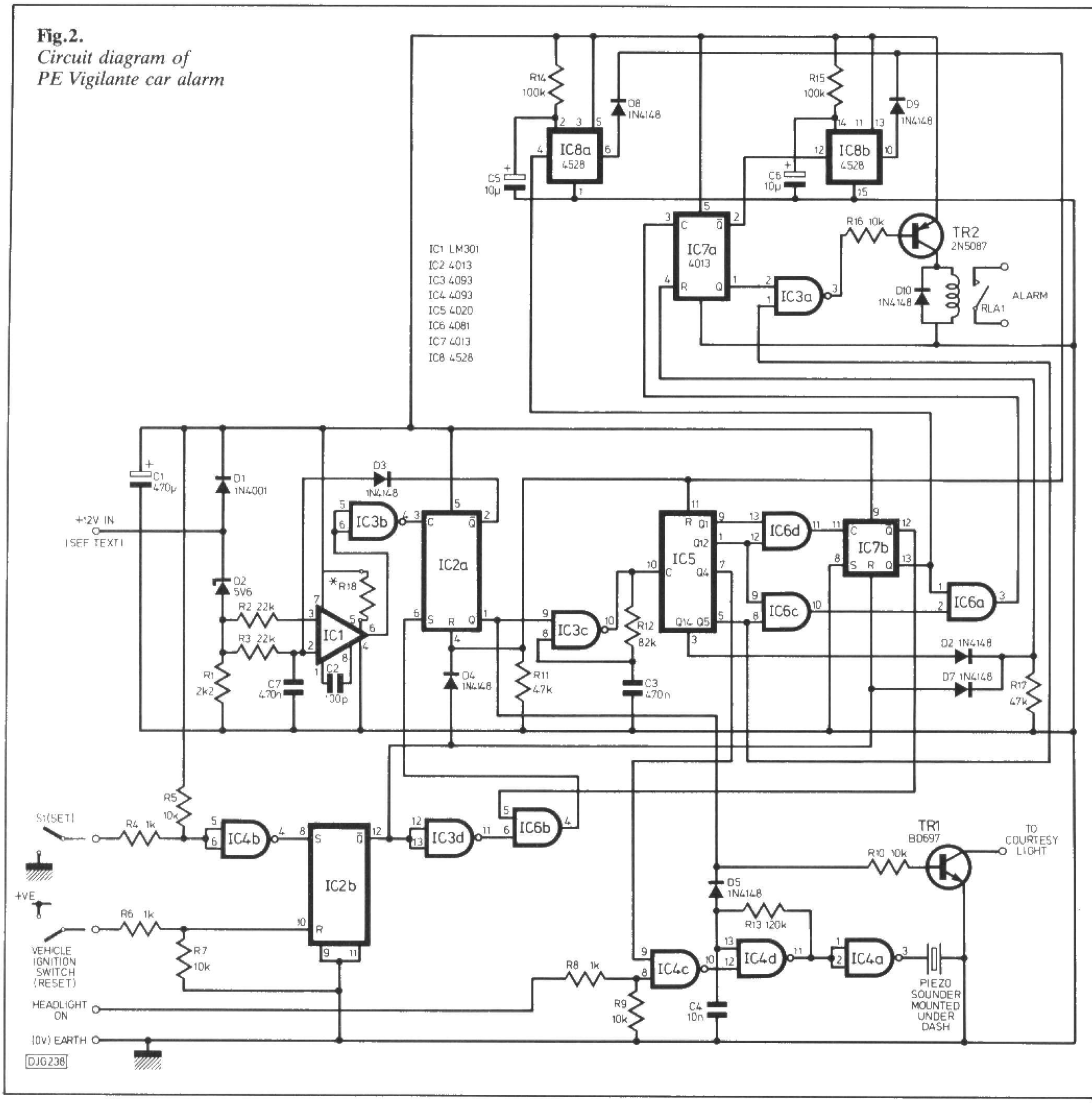


Fig.2.
Circuit diagram of PE Vigilante car alarm

this way, if the lights are on when the warning period is being signalled, the warning oscillator is modulated at a slow rate to act as a "lights on" warning.

The output from the warning oscillator is buffered by gate 4a, and taken to the piezo sounder. As with the Set switch, the other end of the piezo is terminated to vehicle earth. The clock pulses to the counter are counted through, and after the 2049th, pin 11 of gate 6d goes high, which toggles the Exit flip flop 7b. Pin 13 goes high, and 12 goes low. This enables gate 6a by putting a high on pin 1, disables gate 6b, pin 5, and starts the monostable IC8a.

The output of the monostable immediately goes high on pin 6, and this resets the counter via D8 to Ø and puts the Alert bistable into the quiescent mode.

Gates 6d and 6c ensure that the Bark flip flop cannot be set when the Exit flip flop is active, by arranging for one gate to allow through pulse 2049, and the Bark to be triggered by ANDing of 2049 with pulse 2064 in gate 6a.

In this way, the alarm allows the driver to Set, and to Exit, but only once. With the Exit flip flop now having been clocked by the counter, the only way it can be reset is by a high level on pin 10, taken from the Enable flip flop.

The supply is taken off the vehicle wiring at the fused side of interior light circuit. This is smoothed by diode D1, and C1. It is also applied to D2, a 5V6 zener and R1. This gives a voltage of approximately 7 volts at the anode of D2, and slightly less than this at pin 3 of the 301 op amp, IC1. R2 and R3 are equal in value to minimise the effects of input offset currents, and to ensure that there will be minimal voltage difference at the two inputs to the op amp. R3 and C7 form a d.c. storage circuit, slowing down the response time to any change in voltage which may occur.

Resistor R18 is selected to give the required sensitivity to these voltage changes, by feeding in an offset to the op amp, and its value is selected under test. See below for details. When a sudden change *downwards* in the input voltage occurs, the two inputs to the op amp will momentarily become unbalanced. Pin 3 will track the fall, while Pin 2 will effectively remain high for several milliseconds. As soon as this happens the output of IC1 will go low. This change is inverted and buffered by IC3b, and a positive-going edge is applied to the Alert flip flop clock pin 3. The Alert outputs flip over, pin 1 going high, and 2 going low. The clock, warning and interior lights are enabled as before, and D3 is forward biased, discharging

C7, and allowing the output of IC1 to return high.

This is necessary to prevent the circuit retriggering itself. If D3 is omitted there is a strong likelihood that the circuit will not reset, since it also draws current from the battery!

The counter counts up as before, and this time the Bark flip flop is clocked on pin 3, setting pin 1. This high is NANDed with a divided-down output from the counter, and drives the relay by TR2. In the final circuit board design it is possible to cut the track to pin 1 of gate 3a, and join pins 1 and 2, so that the relay is held on instead of pulsing. The counter now continues to count up until Q14, pin 3 goes high. When this happens the Bark flip flop is reset via D6, triggering IC8b, whose output goes high, resetting the counter and Alert once again.

It might appear that the use of two separate monostables is a bit over the top of this circuit, when simple differentiating components would have achieved the same end result. However, in order to keep the impedences of all the resetting low, and in this way maintaining good noise rejection (cars can be very noisy, electronically), the present set up is the most reliable solution. Your neighbours will probably appreciate this more than you do!

Holding the reset to IC2a pin 4 high in this way for a few seconds after turning off the alarm allows the car electrics to settle down prior to enabling the circuit again. This, in conjunction with the time constant formed by R3 and C7 ensures that false retriggering cannot occur.

CONSTRUCTION

The whole circuit is mounted on one p.c.b., with connections to the vehicle using flying leads soldered to tags and secured with cable ties or lacing cord. Bear in mind during construction that the environment in which the circuit is to be used is naturally very prone to vibration. Use shakeproof washers, and so on.

The board is quite small on purpose, so that the case can be small enough to tuck away under the bonnet. The author's alarm was mounted behind the battery, high enough to be dry, and far enough from the engine to be cool. There are quite a few links to be fitted – the price required for a small p.c.b. Fit these first.

The component layout diagram shows clearly where everything goes. Note that the resistors, and even some of the diodes are mounted on end to conserve space. This requires that the leads be bent over close to the com-ponent body. Do this *carefully*, and always allow about 3mm of lead to come out from the component *before* forming the bend.

All the i.c.s. are soldered direct to the board. This prevents them working loose, and problems arising from oxidation. Be careful to ensure that all the i.c.s. are in the right place and the right way round before committing yourself to soldering. If you should happen to solder one in wrongly the best thing to do is carefully cut off the legs close to the i.c., and remove each leg with snipe-nose pliers and iron. Trying to remove the chip to use it again will almost certainly overheat it, resulting at best in an unreliable device. When all the components have been fitted and checked the connecting leads can be fitted.

I found that the easiest way of completing the assembly was to colour-code the wires, noting which colour did what, and cutting off each to about a foot in length. This then allows the system to run up on the bench using a power supply, without having to first measure the cable runs.

One resistor, R18, has to be selected at test, and so cannot be fitted to the assembly just yet. To assist in selecting the value fit two pieces of tinned copper wire of about half inch in length in the position of R18.

When selecting later, the test resistors may be soldered to these leads, avoiding overheating and possible damage to the p.c.b. After the correct value has been ascertained, these pieces of wire are carefully removed and the resistor fitted in their place.

Don't forget to fit the two insulated jumpers to the underside of the p.c.b., one next to IC8, and the other from the emitter of TR1 to the negative side of C1.

TESTING

The equipment required for testing is as follows:

Bench power supply, 13V @500mA.
Multimeter, 20k ohm/V minimum, 20V range, and current, 20mA range, or the best you can manage.
Oscilloscope, single beam, or see text below.
Jumper-lead with croc-clips on each end,

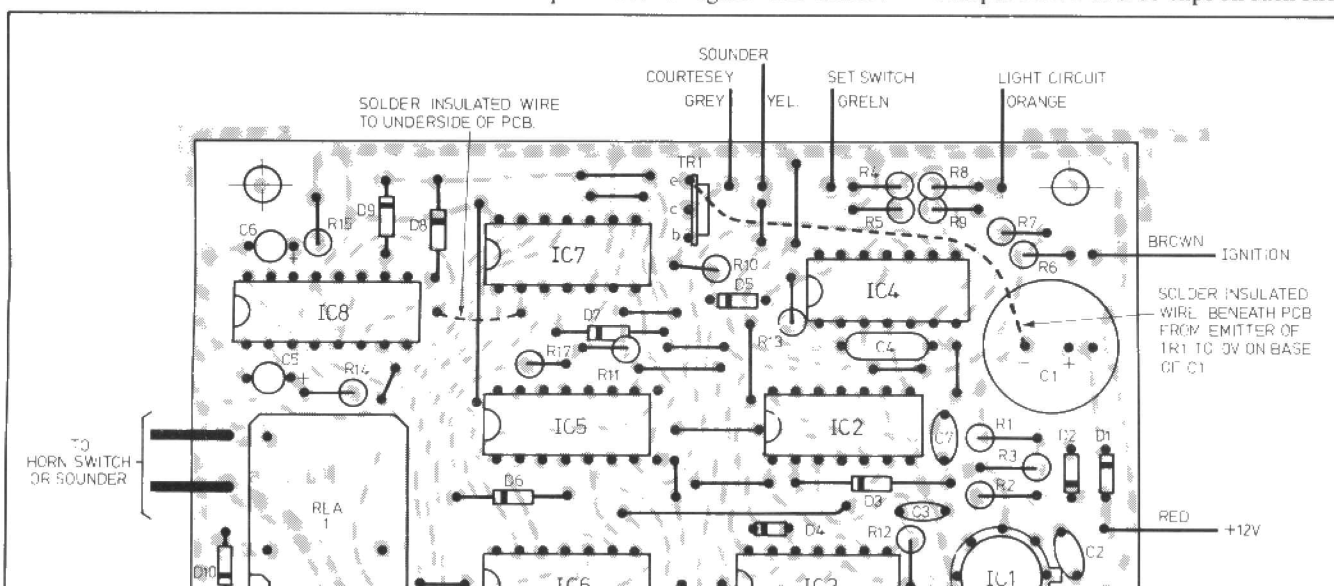


Fig.3. *Details of the printed circuit board*

about a foot in length.
12V bulb in holder, but rated at about 6 watts
Selection of resistors from 100Ω to 1k.

Connect up the board via the ammeter, and check that the total current drawn does not exceed 10mA, and there are no overheating components. Disconnect the current meter and reconnect it to the supply. Check that the voltage present at the anode of D2 is V+ less 5.6V, about 7V.

Power down and solder a resistor of about 2M2 on the temporary connections for R18. Then connect the jumper lead to V+ and the cathodes of diodes D8&9. Connect the scope to pin 6 of the op amp, ensuring that the probe does not short out adjacent legs. Apply power and monitor the scope.

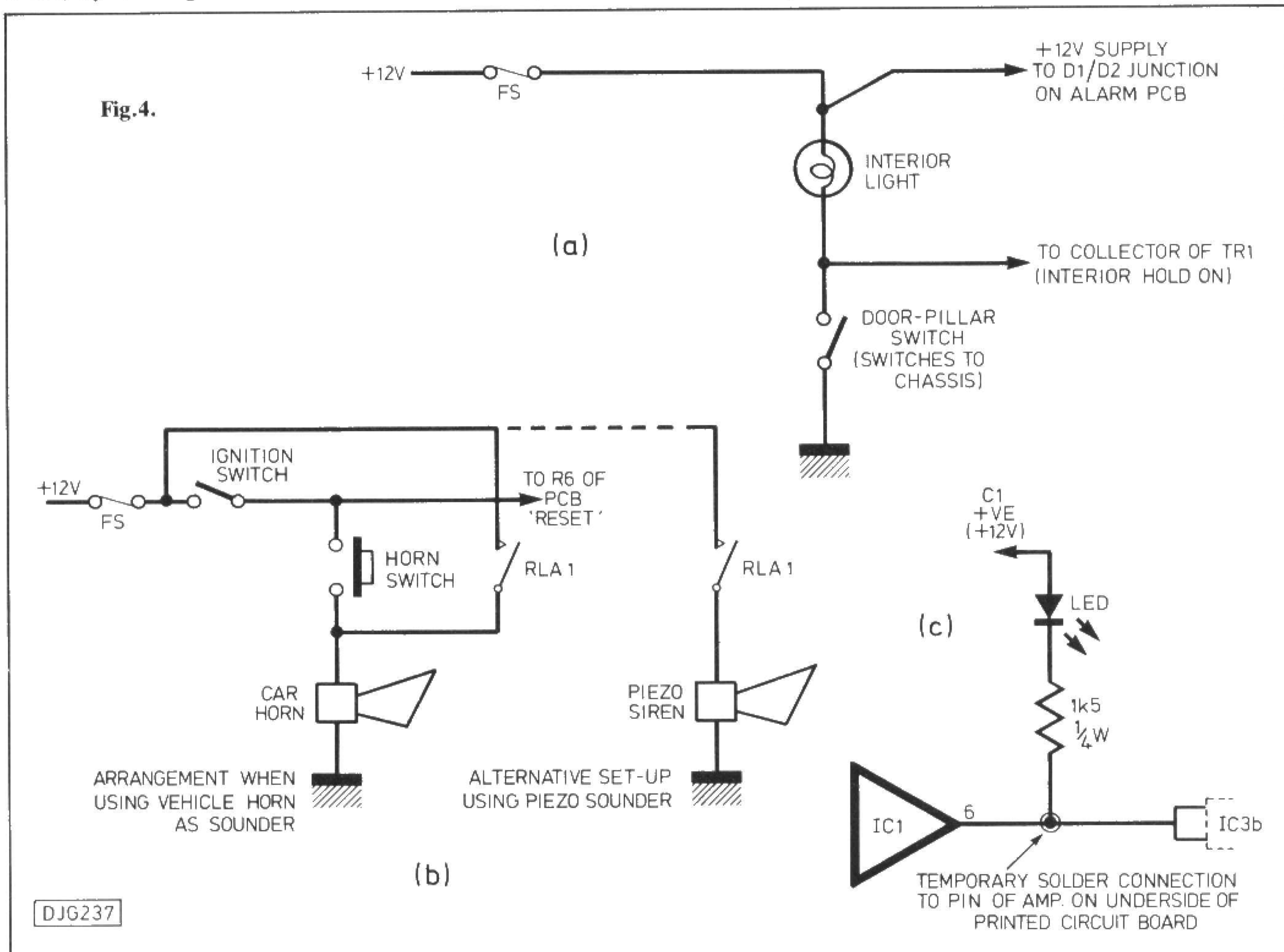
The output of IC1 must be high. If it is not, try reducing the value of R18 to 1M. If you cannot get this stage to work properly, go back and check the voltage across D2, the orientation of IC1, and all the associated components.
for this to work correctly enough time must be allowed between 'dab-ons' to enable C7 to charge to its full potential. So give it about a couple of seconds.

What you are now doing is selecting the amount of offset to feed in to the op amp, by changing the value of R18 so that the monitor just switches when a load resistor of about 330Ω is touched onto the supply leads. By altering the value of R18 and the test resistor the sensitivity of the monitor should be such that it will trigger the output when a genuine alarm condition occurs, and will be quite insensitive to false alarms. When the value for R18 is set, the temporary wire connections can be removed, and R18 soldered into place. It is not a bad idea to check the result after it has been fitted into place.

In several tests carried out the value for R18 was found to lie in the 1M to C3 will also change the timing of the whole circuit. In this way you may tailor the Exit time to individual needs. For example, a disabled person may require a lot longer to switch off the alarm or to exit, and this can be taken into account. The time that the alarm will sound for, however, will remain at three times that of the Exit. Of course there is no reason why the experienced constructor should not do some track cutting under the timer...

The values suggested for R13 and C4 will give an output frequency to the piezo of about 3.5kHz. Since individual piezos tend to differ in their characteristics, it would be as well to check the sound level obtained at test, and play

Fig.4.



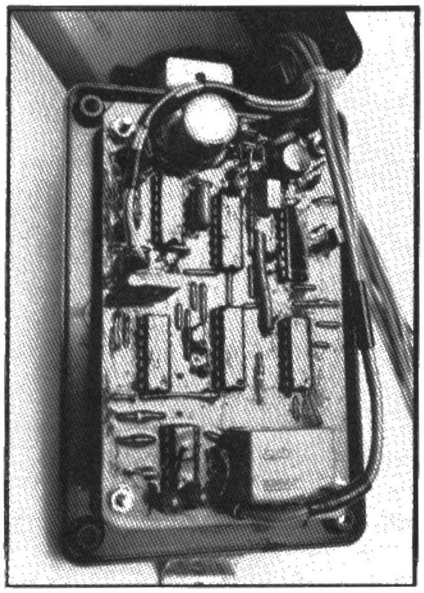
If you do not have a scope, the l.e.d. circuit (Fig.4.c.) will give enough of an indication for the purpose of setting up the op amp.

Having arrived at a situation where the output of IC1 is high, keeping one eye on the output, load the supply with one of the low value resistors, say, the 1k. By progressively reducing the value of the load resistor you can determine the point at which the output of the op amp no longer changes. Don't forget that 3M3 regions, depending upon the tolerance of R2, R3 and the op amp. Increasing the value of C7 has the effect of increasing the sensitivity of the op amp. This is the only part of the circuit which requires any setting up. Hereafter the whole is digital, and is consequently a case of following through the levels in case of trouble. The circuit will output its two states, Warning and Alarm, in a 1:3 relationship.

Changing the value of either R12 or on the warning oscillator is intermittent. Connect the 12V bulb to the collector of TR1. Check that the light is on during the Exit period, and during the warning and alarm period.

Connect the bulb circuit across the relay, and check that it turns on during the alarm period. During this period operate the reset, by jumpering supply to R6, and make sure the alarm turns off immediately.

Apply a couple of blobs of silicon



with values to get the maximum.

Connect the jumper to supply, and to R8, simulating the "lights on" condition. Check that when the circuit is switched rubber to either side of TR1, to prevent it vibrating and possibly being damaged. Tie the wiring into neat cableforms, not so much for looks as for support, and spray the whole assembly with protective lacquer. If you haven't any lacquer, one of the moisture repellent sprays will do. Mount the p.c.b. onto the lid of the box, using plastic stand-offs and shakeproofs and seal the nuts in place with more blobs of silicon to prevent them working loose. Feed the cableform through the grommet, and assemble the box. When all is in place the space left round the wires also can be sealed with silicon compound.

The whole assembly is then ready for fitting to the vehicle.

FITTING

Provided the flying leads have been left about a foot long this is fairly straightforward, requiring a set of crimps with butt connectors, spades, and eyes to complete. If you should be tempted to use a soldering iron out of doors, be very careful. The only safe way is to put an Earth Leakage Trip between the mains and the iron, but if possible use crimps.

Choose a well protected place for the alarm, away from heat and dampness, and secure the box using self-tappers and shakeproof washers. The earth connection can be made here also. Disconnect the negative (earth) side of the battery. Using butt connectors, run wires to the interior lamp switch mounted in the door pillar, and the live side of the interior lamp itself. This latter connection is the +12 supply. Drill out a hole and fit S1 in any convenient spot on the dash. Using a double-sided sticky pad, the piezo can be mounted under the dash. Connect these to the main alarm. Take both of their return lines to the chassis.

Connect the switched side of the ignition and the live side of the light circuit to the appropriate wires to the alarm. Reconnect the battery, and momentarily turn on the ignition, resetting all the flip flops.

Carry out a quick check of the system, particular that operating the ignition switch will turn the system off! Provided all is well, using heavy (15A) cable connect up the alarm sounder. This may be either the vehicle horn or one of the low-current piezo sirens. Make sure that if you choose the piezo, it is self-contained siren, and not a horn requiring an a.c. input to drive it.

Whether or not you include the lights in the Bark mode is a matter of personal taste. In that case, a separate relay will have to be fitted in order to carry the current, although many modern cars already drive the lights through a relay, and it may be possible to plumb into this wiring.

Don't forget: in order for the alarm to work the interior light must turn on when the doors are opened! Most car manufacturers, or spares shops can supply extra door pillar switches, and these should be fitted to the rear doors in the case of a 4-door vehicle.

You will find that operating the lights with the alarm on will draw enough current to trigger the alarm and, in the author's case, turning on the radio does as well! Once the lights are on, the alarm should set and operate correctly. If it doesn't, then you've probably got the sensitivity set too high. Back to the test bench, and try reducing the value of R18.

Protecting the bonnet or boot is a matter of fitting a switch to each, and connecting it in to the interior light circuit. If your car already has them fitted to lights, then you may find these will draw enough to trigger the alarm. If not, then a little rewiring should do the trick. While you are carrying out your tests don't forget the sound of the alarm might be music to your ears, but is unlikely to be so to your neighbours, so take care when testing.

In some instances it might be necessary to fit an external reset switch, in place of the ignition. This is easily done provided you bear a couple of things in mind. It is a good idea to isolate the V+ line to the switch with a low value fuse, say, 250mA, in an in-line fuse holder, just in case the cable should accidently short to earth. The switch must be mounted in such a place as to minimise the amount of dirt and water that will come into contact with it. It should be of the type recommended for use outside. As mentioned earlier, the system will operate automatically if desired. Shorting out the Set switch, S1, so that the input to the alarm is always low, will do this. Each time the ignition is switched off the Enable flip flop will be set. This particular option was found by

If the Bark device is the vehicle horn, the author to be a real pain.
try to make sure that the wiring cannot easily be tampered with from the underside of the vehicle.

This completes the fitting, and now all you have to do is remember to set it, and to close the windows and lock the doors, and hopefully your pride and joy will remain so until it goes for that final run to the great scrapyard in the sky when *you* decide it should! PE

COMPONENTS

RESISTORS

R1	2k2
R2,R3	22k (2 off)
R4,R6,R8	1k (3 off)
R5,R7,R9,R10, R16	10k (5 off)
R11,R17	47k (2 off)
R12	82k
R13	120k
R14,R15	100k (2 off)
R18	see text

All resistors ¼W, 5%

CAPACITORS

C1	470µ 16V
C2	100pF disc
C3,C7	0.47µ/50V layer (2 off)
C4	10n disc
C5,C6	10µ/16V tantalum (2 off)

DIODES

D1	1N4001
D2	5V6 zener
D3,D4,D5,D6, D7,D8,D9	1N4148 (8 off)

SEMI CONDUCTORS

TR1	BD697 Darlington
TR2	2N5087 or equiv.
IC1	LM 301 op amp
IC2,IC7	4013 dual flip flop (2 off)
IC3,IC4	4093 quad NAND Schmit (2 off)
IC5	4020 counter
IC6	4081 quad AND
IC8	4528/4538 dual monostable

MISCELLANEOUS

Piezo Sounder Maplin FM59P, S1 push to make sub-min, RLA1 12V, s.p.c.o. rated at least 10A (eg. Maplin YX97F), case (Verobox 303), Grommet, nuts, bolts, shakeproofs, wire, crimp connectors, turret tags, en.cu.wire, insulating sleeving, cable ties, mounting bracket, self tapping screws, p.c.b., etc.

SWITCH MODE PSU DESIGN

BY ROBERT PENFOLD

The fundamentals of switch mode operation

Switch mode power supplies have certain characteristics which make them well worth the extra trouble of designing for some applications.

SWITCH mode power supplies are one of those things that most electronics enthusiasts will have heard of, and many will have a vague idea of the principles involved, but relatively few people seem to be fully conversant with the basics of their design and operation. In view of the fact that power supplies of this type are now quite commonplace in commercial equipment, it is perhaps surprising that so few have so far appeared in designs for the home constructor. No doubt the situation will change in due course as the techniques and the technology becomes widely understood. Designing a switch mode power supply is certainly a good deal less straightforward than producing a circuit for a convential type having a comparable specification, but there are definite advantages to the switched mode approach.

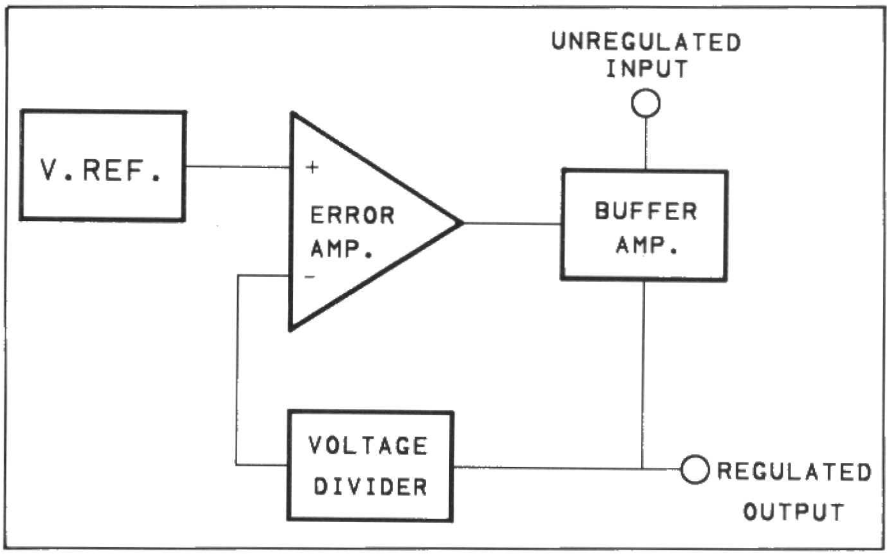


Fig.1. *Block diagram for a conventional series regulator.*

SWITCHED MODE BASICS

It would perhaps be as well to start with the basics, and to explain just what is meant by a switched mode power supply. There are actually several different types of switching power supply, and variations on each of these. Some are intended for voltage step-up or negative supply generation, others are for use as more efficient replacements for conventional regulators. We will start by considering the latter.

Consider the block diagram of Fig.1. which is for a conventional high quality power supply having a linear mode output device. This is based on an "error" amplifier, which is really just a differential amplifier, and in practice is often an operational amplifier such as the 741C. The non-inverting input of the device is fed with a well stabilised reference voltage which would typically be obtained from a zener diode fed from a constant current source. The precise reference voltage is not that important, except in that the output voltage of the power supply can not be set at a figure which is less than the reference potential. Consequently the reference voltage is often quite low at around 2 volts.

The output of the amplifier feeds the input of a buffer amplifier which enables high output currents to be supplied. If quite low currents are required the buffer stage can be dispensed with and the output is then taken direct from the error amplifier. The output of the supply is coupled to the inverting input of the amplifier via a potential divider circuit, and this gives what is really a conventional negative feedback arrangement with the amplifier operating in the non-inverting mode. With the output coupled directly back to the inverting input there is 100% negative feedback, the amplifier has unity voltage gain, and the output voltage is equal to the reference potential. Using a potential divider in the feedback network introduces voltage gain, and the output voltage is boosted. The feedback is simply maintaining the inverting input at the same voltage as the reference level at the non-inverting input, and in doing so it stabilises the output at this level, or some multiple of it. Note that the feedback is taken from the output of the buffer stage and not the error amplifier, so that the feedback compensates for any changes in the output voltage due to variations in the loading on the buffer stage. In fact some high quality bench power supply units have a feedback input so that the feedback can be taken via the non-earthy output lead, so as to compensate for any slight losses through the lead.

With a conventional series regulator the output voltage is controlled by biasing the output device more or less heavily, as necessary, in order to maintain a constant output voltage. With a switching regulator the output device is either biased hard into conduction or is fully switched off, and is only in an intermediate state during the short transistion between these two states. The output from the buffer stage is therefore a series fo pulses, and it is the average output voltage that is being stabilised by the circuit. This may seem a bit useless on the face of it, but in order to give a well smoothed output from the pulse signal it is merely necessary to add a lowpass filter at the output. The output frequency is generally quite high at about 100 to 200kHZ, and obtaining a low ripple output is not very difficult.

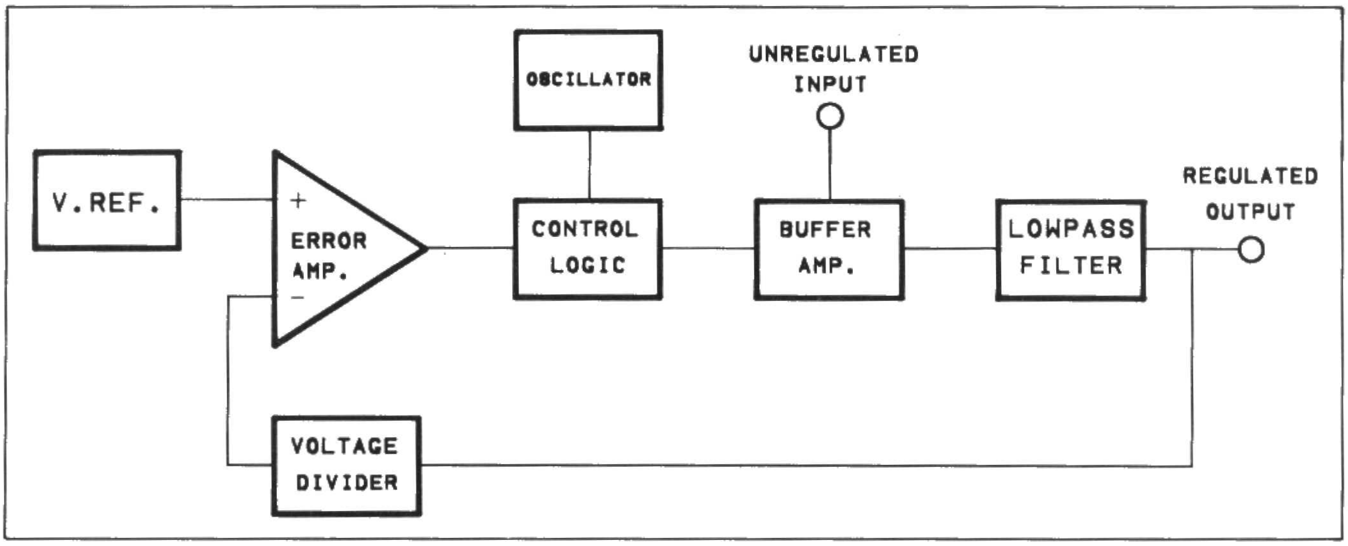


Fig.2. *The basic arrangements for a switched mode PSU.*

If we look now at the switch mode power supply block diagram of Fig.2., this is very much the same as the linear version, but a control logic circuit has been interposed between the error amplifier and the buffer stage, and a lowpass filter has been added at the output. The negative feedback must, of course, be taken after the lowpass filter and not from the output of the buffer amplifier. An oscillator feeding into the control logic circuit controls the output frequency.

There are any number of ways that the mark-space ratio of the output signal can be contolled to give the required average DC output voltage, and some methods are very much more complex than others. The classic approach to pulse width modulation (p.w.m.) is the arrangement outlined in the block diagram of Fig.3. This merely has the input voltage fed to the inverting input of a voltage comparator and a clock signal fed to the non-iverting input. It is essential to the operation of the circuit that the clock signal has a triangular waveform.

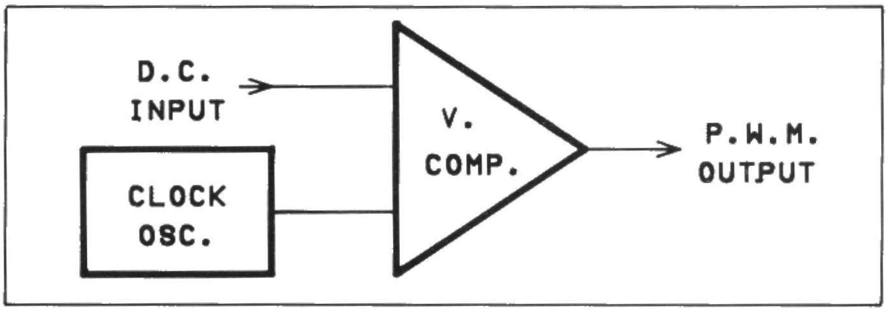


Fig.3. *The classic method of pulse width modulation.*

The waveform diagrams of Fig.4. illustrate the way in which this simple set up provides the pulse width modulation. In each pair of waveforms the upper one is the clock signal and the lower one is the pulse output signal. The two broken lines represent the input voltage and average output voltage. In (a) the input potential is half way between the peaks of the clock signal, and the output signal is therefore a squarewave with a 1:1 mark space ratio. The average output voltage is about half the supply potential.

In (b) the input level has been increased, and as a result of this the clock signal is higher than the input voltage for only about one quarter of the time. This gives an output signal with a 3:1 mark space ratio, and an average output potential of about 75% of the supply voltage. The input level in (c) has been decreased, and the clock signal is consequently at a higher level than the input signal for about 75% of the time, giving an output with a 1:3 mark space ratio, and an average voltage of a quarter of the supply voltage.

If carefully designed, a pulse width modulator can provide an average output voltage that is virtually identical to the input voltage over a wide range. For the present application this is not really necessary though, and the negative feedback action of the voltage regulator circuit will tend to compensate

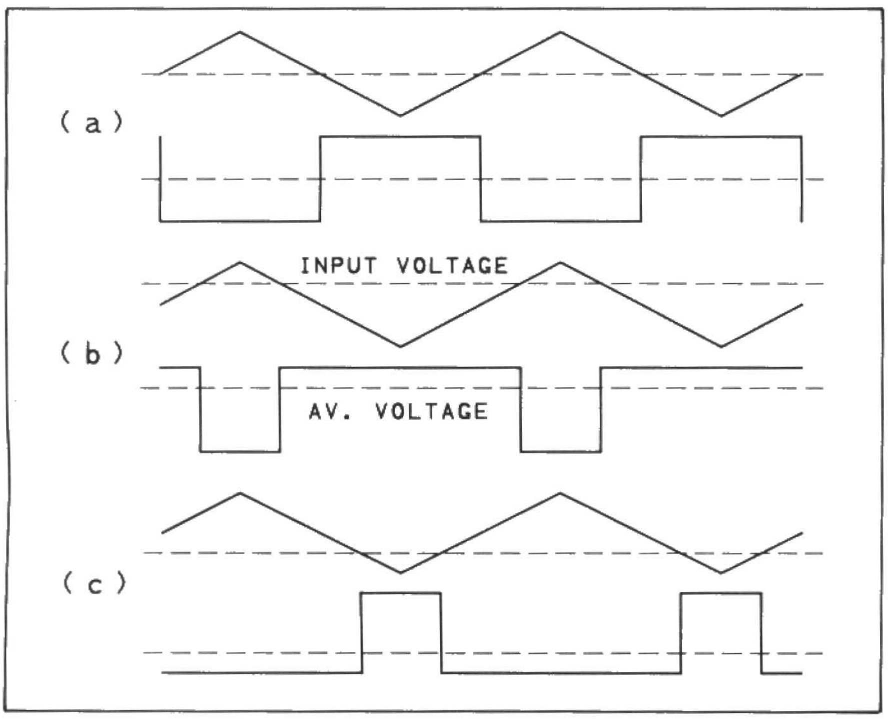


Fig.4. *Pulse width modulator waveforms.*

for any DC offsets through the pulse width modulator, and for any voltage gain or attenuation. For the system to work properly the input voltage must remain within the voltage range covered by the clock signal though, so that changes in the input voltage always give some change in the average output potential.

Although this system may be the most common approach to pulse width modulation, there are other ways of achieving the same ends. It is not even necessary to have a fixed frequency arrangement in which both the mark and space durations vary. Much the same effect can be obtained by having either the mark or the space duration fixed, and varying the input frequency. It is usually the mark (positive output) time that is fixed, and the average output voltage is increased by raising the input frequency so that the output pulses become bunched up, or reduced by decreasing the frequency so that they are more spread out. This arrangement is basically just a voltage controlled oscillator (v.c.o.) feeding a non-retriggerable monostable multivibrator.

SWITCHED ON

This may seem to be all very clever but a total waste of time, and it would be reasonable to ask "why bother"? There are in fact a number of advantages to switched mode power supplies, although it has to be admitted straight away that in the some power supply applications these are simply not applicable, and the honest answer to the question sometimes would be "none at all".

One advantage of switch mode power supplies, and the one which often makes them the most attractive proposition for use where a variety of different supply voltages are required, is their ability to provide a wide range of output voltages from a given input potential. With a normal series regulator the output voltage can only be less than the input voltage as the circuit functions by providing a variable voltage drop between the unregulated input and the regulated output. A switching regulator can operate in a comparable mode, but it can also provide a voltage step-up, and it can even generate a negative supply from a prositive input (or vice versa). This is a topic that will pursue in more detail shortly.

The other main advantage of switching regulators is their high efficiency. The fundamental reason for this is that the switching transistor is, by the nature of things, normally either switched hard on or fully switched off, and in neither state does it dissipate a great deal of power. In fact there is no significant dissipation in the device when it is switched off as although the voltage across it may be quite high, the current flow is extremely low indeed. When the device is turned on it will pass quite an appreciable current, but the voltage across it will be quite low. This voltage will not be totally insignificant though, and would typically be a volt or so. The power dissipated by the device during the on period could therefore be a few watts if output currents of a few amps are involved, although things are mitigated somewhat overall by the fact that the device may well be switched off for around 50% of the time, giving a corresponding reduction in the average dissipation. The output transistor may have to handle relatively low power levels, but a power device is often needed in order to reliably handle the voltages and currents involved, and the power level may be beyond the capabilities of a small signal device anyway. A minimal amount of heatsinking will normally be sufficient though.

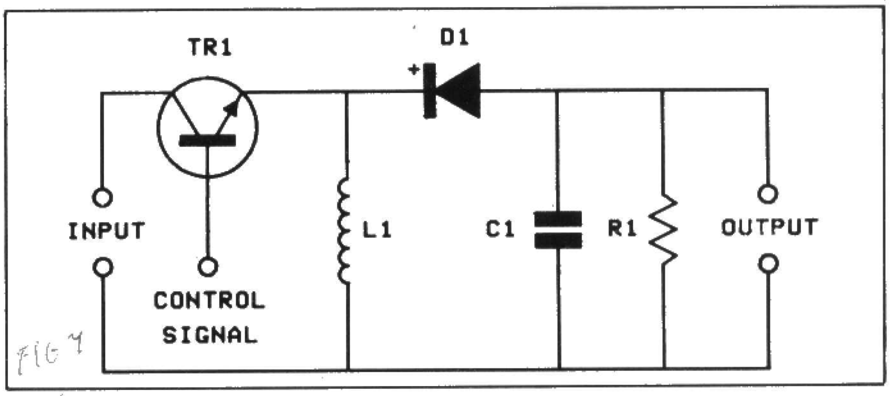


Fig.5. *The basic step-down output configuation*

A useful spin-off from the lack of dissipation is that the circuit can provide a low output voltage from a relatively high voltage source very efficiently, providing an effect that is comparable to a transformer which gives a voltage step-down in an a.c. supply. On the face of it there is no way that the output current can be higher than the input current, but in average terms this is possible. Assume that the input is at 15 volts and that the pulse width modulator has an output signal with a 1:2 mark space ratio. If we ignore any losses in the output transistor, this results in an output voltage of 5 volts, since the supply is switched through to the output for one third of the time, and one third of 15 volts is 5 volts. If the output current is (say) 600 milliamps, then the input current is pulsed at the same figure, but with a 1:2 mark space ration this gives and average input current of 200 milliamps. The filter at the output intergrates 15 volts 600 milliamps pulses into reasonably steady 5 volts at 600 milliamps, and a smoothing capacitor at the input can similarly convert the input signal from pulses to an almost constant 200 milliamps.

Of course, calculations of the type provided above are about as valid in practice as theoretical transformer calculations. In practice there will be losses in the switching device and the output filter, and unless there is a fairly substantial difference between the input and output voltages the input current may still exceed the output current.

SWITCHED OFF

Switching regulators may have very definite and worthwhile advantages over ordinary series regulators, but they are not without drawbacks, and they are unlikely to completely replace conventional designs in the near future. The main problem is one of increased cost and complexity, and with three terminal monolithic voltage regulators costing a matter of pence they are

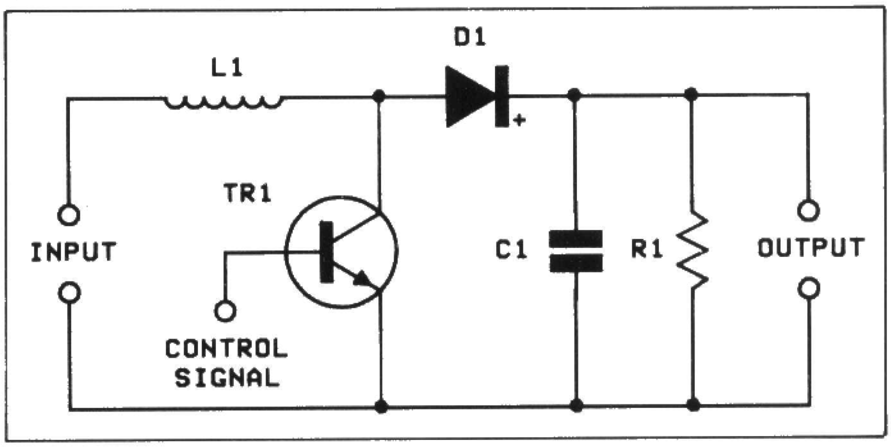


Fig.6. *The basic booster or step-up output configuration.*

normally a much more sensible choice than a switching regulator. Another problem with switching regulators is that they are more difficult to design, and unless carefully designed would be likely to have poor reliability. They are likely to to be somewhat less reliable than ordinary series regulators anyway, since they generally have more circuitry and therefore have more opportunity to fail. For the home constructor there is also the difficulty of obtaining a suitable inductor for the output stage. Suitable ready-made components are not exactly available "off the shelf", and it is generally a matter of obtaining a pair of pot cores and some enamelled copper wire and winding the component oneself.

There are also problems associated with the switching process that can not be totally ignored. The obvious problem is that of obtaining a really low noise output. This may not always be necessary, especially bearing in mind that they will be predominantly at high frequencies, and will consequently tend to be less of a problem than the normal mains "hum". It could cause difficulties in some applications though, such as in radio receivers and test gear applications. While it is not impossible to obtain really low levels of output noise it is generally a little more difficult than with a conventional regulator with its inherently low noise output.

Another problem associated with the switching is that of radio frequency interference beng radiated. To minimise this there should only be short leads in the wiring to the output filter and output stage, and where possible only short output leads should be used. Overall screening of the supply and using a type of inductor that radiates a weak field also helps.

OUTPUT STAGES

There are three basic types of output stage for a switching regulator (plus numerous variations on these), and these provide totally different functions. The only type we have considered so far is the step-down type, which is used as a more efficient version of a conventional series regulator, but there is also an output configuration that will provide a votage step-up, and another that gives an inversion (which in this case means a negative supply from a positive one, or vice versa).

If we take the output stage used in the step-down configuration first, this is as shown in Fig.5. Circuits which use this type of output stage are sometimes called "buck" regulators incidentally, which is the American name. TR1 is an emitter follower switch, and when it comes on, the voltage at its emitter rises to virtually the full input voltage. This gives a voltage across L1 which is almost equal to the difference between the input and output voltages, and this results in a steadily increasing current through L1, into C1, and the load. This continues until TR1 turns off, and the stored energy in the inductor (which is of reverse polarity) if fed via D1 into smoothing capacitor C1. When TR1 turns on again, current flows through L1 and into C1 again, and so on.

This is really just a standard L – C smoothing circuit and things are only complicated by the inclusion of D1. This is necessary due to the one-sided driver stage which otherwise fails to provide a path to earth for L1. If a complementary output stage was to be used D1 would be unnecessary, but obviously it is more economic to use a diode here rather than another output transistor. R1 is a load resistor, and this is needed to ensure correct operation of the circuit if the output is left open circuit, just the same as with a conventional series regulator. Normally it is not necessary to include a load resistor as the potential divider in the negative feedback network will provide a suitable resistance across the output.

satisfactory results in this application. The inductor needs to have a reasonably high Q value and it must work efficiently at the (probably) quite high currents involved in this application. This generally means using a pot core or some similar type of ferrite core as the basis of the component.

The basic inverter or "buckboost" configuration is shown in the circuit diagram of Fig.7. The American "buckboost" name is an appropriate one, as it has features in common with both the step-down and boost circuits. As in the step-down configuration, TR1 operates as an emitter follower, but when it is turned on it drives current into L1, as in the booster circuit. When TR1 switches off, L1 again produces a reverse voltage, and D1 conducts this into C1. When TR1 switches on again D1 prevents a positive charge from being fed from the input to C1 by way of TR1. Thus a reverse polarity supply is produced across C1.

It is assumed here that a negative output signal is being generated from a positive input, but the opposite type of

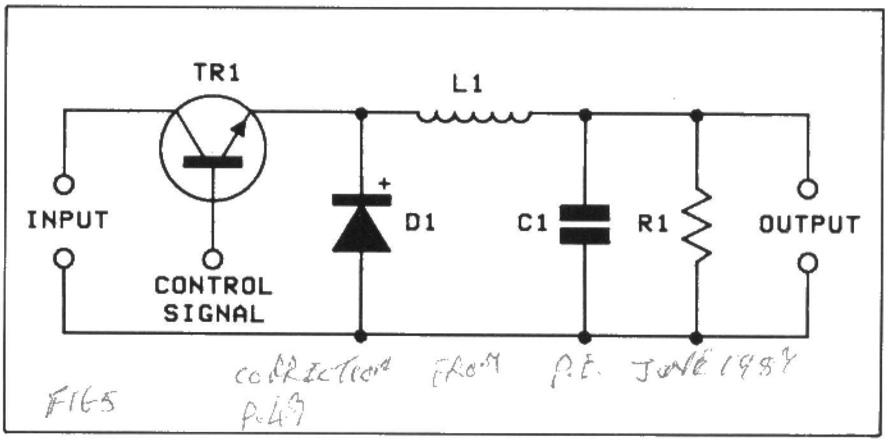


Fig.7. *The basic buckboost output configuration.*

The basic boost output stage circuit appears in Fig.6. In this configuration the switching transistor operates in the common emitter mode, and when it is switched on a current flows through L1 and it stores energy. When TR1 switches off, the magnetic field around the inductor collapses rapidly, generating a reverse voltage and releasing the charge stored in the component. With the input end of L1 negative and D1 end postive, the output from L1 is connected in series with the input voltage and adds to it. D1 allows this voltage to charge C1, but it prevents C1 from discharging into TR1 when this device switches on again.

An important point to realise about the boost circuit is that the reverse voltage generated across L1 when TR1 switches off can be considerably greater than the input voltage. Thus the circuit is not limited to voltage doubling, and with an apposite inductor it can provide a considerable voltage boost. Note however, that a simple ferrite cored choke for RF use is unlikely to give

conversion can be obtained merely by reversing the input polarity, changing TR1 to a pnp device, and reversing D1.

Like the booster circuit, the use of an efficient inductor is essential if this type of output stage is to operate well.

SWITCHING ICs

Switch mode power supplies can, and sometimes are, produced entirely from discrete components, but there are many integrated circuits for switching power supply applications, and these make things very much easier. We will not consider any practical devices here as this article is concerned more with the fundamentals of operation than practical circuits. Also, some switched mode power supplies are featured in a separate article and there is no point in duplicating information provided in the other article. However, looking at things in broad terms, most switch mode power supplies have an internal arrangement along the lines of the block diagram shown in Fig.8.

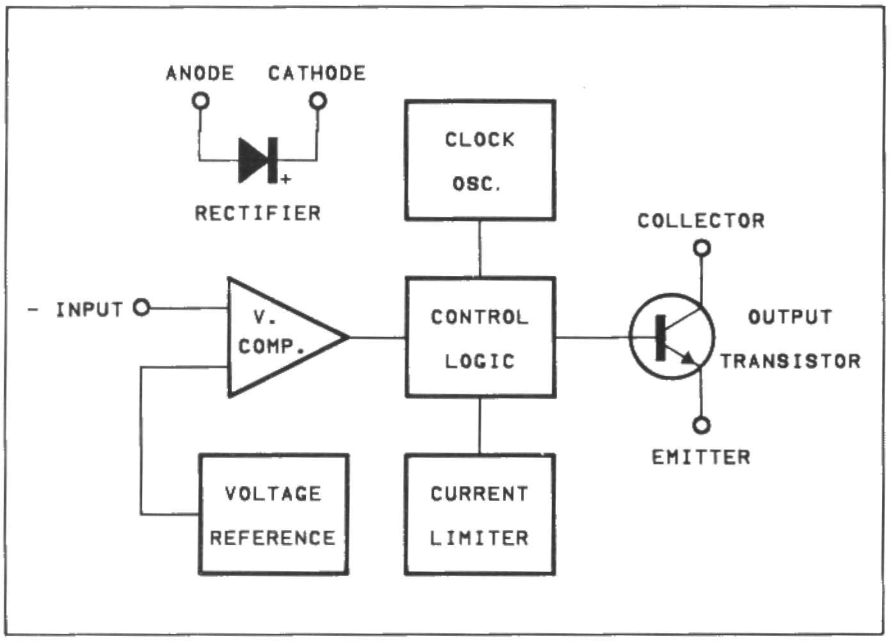


Fig.8. *Typical arrangement for a switching mode power supply chip.*

An internal reference voltage generator, which would normally be a very high quality type, connects to the non-inverting input of the voltage comparator which acts as the error amplifier. The inverting input is fed from the output via a discrete feedback network. The output of the comparator feeds a control logic circuit which, together with the clock oscillator provides the pulse width modulation. There is often additional circuitry associated with control logic block, and a "standard" feature is some form of current limiting circuit. It would be quite possible to add a conventional current limiter circuit after the output filter but before the feedback take-off point (so that the feedback compensated for any voltage drop through the limited circuit). This would be an inefficient way of doing things though, as the pass transistor in the limiter would need to be a power type, and would dissipate quite a lot of power under overload conditions. It is therefore more normal for the current limiter to reduce the output voltage by controlling the output waveform via the pulse width modulator. A discrete resistor in the supply path is used to set the limit current, and this normally operates in conjunction with an operational amplifier instead of the conventional current limit type circuit where a transistor is turned on when the voltage across the resistor reaches about 0.65 volts. The advantage of using an operational amplifier or some similar arrangement is that it can operate with a much lower activation voltage of typically only about one tenth of that associated with conventional limiter circuits. This avoids the need for a high wattage resistor and helps to give the circuit good efficiency. In fact this feature has the same advantages when applied to an ordinary series regulator, and is incorporated in some of the more recent designs for these.

The output transistor is usually left with both the emitter and collector terminals unconnected, so that the device can be operated in either the common emitter or the emitter follower mode, as the mode of operation dictates. A rectifier for use in the output stage may also be included.

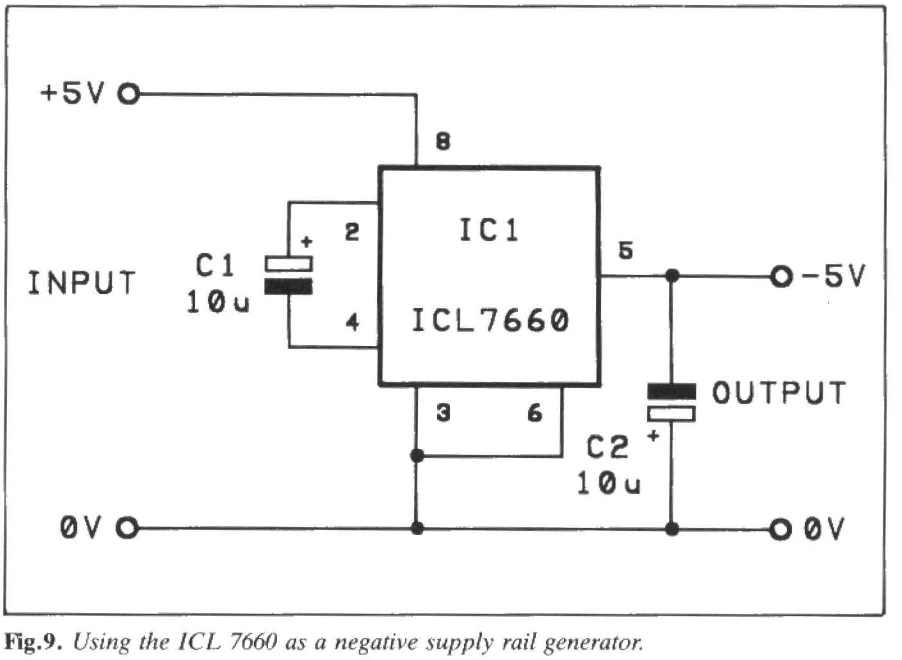


Fig.9. *Using the ICL 7660 as a negative supply rail generator.*

OTHER TYPES

The three types of switching regulator described above are the standard types, but ther are totally different types of switch power mode supply. A type of switching power supply which was at one time probably the most common, but which is relatively rare these days, is the transformer type. Some of these are for use in DC to DC converter applications, like the types described above, but they have the advantage of providing an output which is isolated from the input. A similar arrangement is used in some mains power supplies where the mains supply is converted to a DC signal, and then chopped at high speed and fed to an isolation transformer. This system may not seem to have a great deal to recommend it, but the main point in its favour is that the relatively high operating frequency of the signal fed to the transformer enables it to be much more efficient than an ordinary mains transformer, so that the power supply can be very compact and will run comparatively cool.

A more common type of DC to DC converter these days is the transformerless and inductorless type. These are sometimes just an oscillator feeding a rectifier and smoothing circuit which is either configured to add the output of the smoothing circuit to the input supply so as to give a boost, or to generate a negative supply. An alternative type uses semiconductor switches to give a voltage boost or negative output. Probably the best known device for use in this type of supply is the ICL7660. This operates in the basic circuit of Fig.9., but Fig.10. gives a better idea of how it generates a negative supply rail.

S1 is an electronic DPDT switch that is switched continuously from one position to the other by an oscillator which operates at a fequency of around 10khz. When the switch is in the position shown in Fig.10. it connects Ca across the positive (input) supply, and it therefore charges to +5 volts. When S1 is set to the opposite position, Ca discharges into Cb until the charge voltage on the two capacitors is equal. The basic action of the circuit is therfore to transfer power from the positive

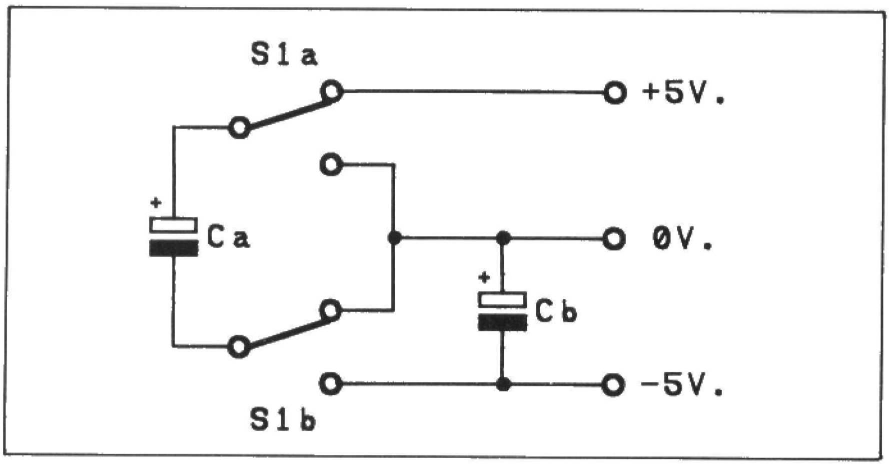


Fig.10. *The ICL 7660's basic methods of operation*

supply rail to the negative output by repeatedly charging Ca from the former and discharging it into the latter. Note that the switching is arranged so that Ca connects to the negative output rail with the correct polarity. C1 and C2 of Fig.9. are the equivalents of Ca and Cb of Fig.10. Switching supplies which use this chargc transfer porcess are called "charge pump" voltage converters.

This basic system can be made to operate in reverse, and if the negative supply rail is used as an input a positive output will be produced on the positive supply rail. The ICL7660 is not designed for use in this manner though, and should not be driven in this way. This basic system can be modified to provide voltage boosting, or inverting with an output voltage greater than the input potential. It is a relatively crude way of doing things though, and the output tends to have a high ripple level and poor regulation. The high ripple is due to the simple output filtering, while the poor regulation, is due to the series resistance of the electronic switches with no feedback and control system to compensate for this. It is possible to overcome these problems, but at the expense of reduced efficiency and increased complexity. Supply circuits of this type are generally only used where poor regulation and a fairly high ripple level are not important. They are also mainly restricted to low current applications where the voltage drop through the switches will not be sufficient to seriously deplete the output voltage. The ICL7660 has a typical series resistance of 70R, giving a voltage drop of 0.07 volts per milliamp of output current (e.g. 4.65 volts with an output current of 5 milliamps).

CONCLUSION

Circuit designers generally try to avoid multiple supply rails wherever possible, but despite improvements in integrated circuits over the years there still seem to be few circuits of any complexity which operate off a single supply. Switch mode power supplies of one kind or another therefore seem likely to be in demand for some time to come, and a likely development is for more integrated circuits to hve them built-in. This is already a feature of the MAX232C device, which is an RS232C serial interface line driver and receiver. It requires only a +5 volt supply, and generates its own +10 volt and −10 volt supplies to enable standard RS232C output levels to be generated. PE

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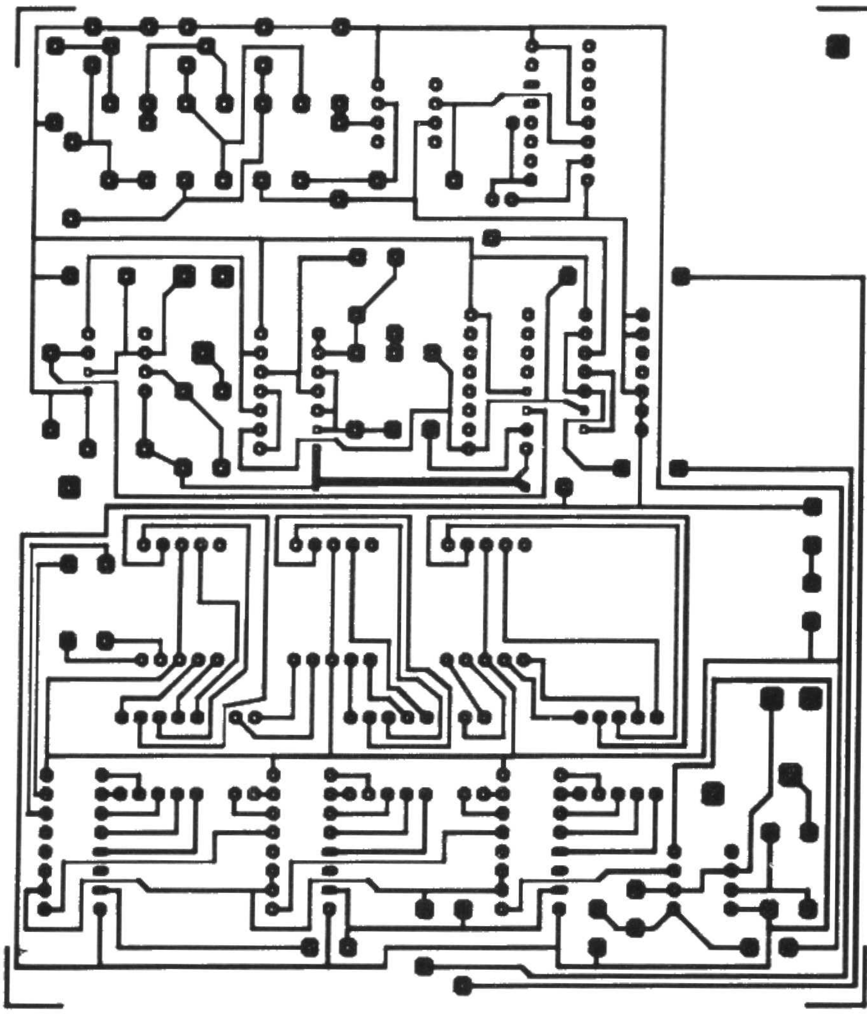

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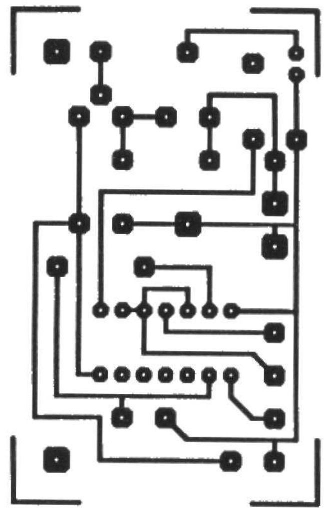

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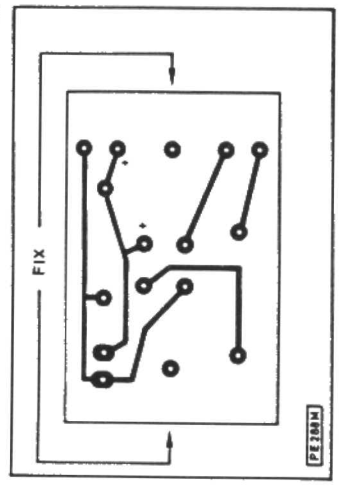

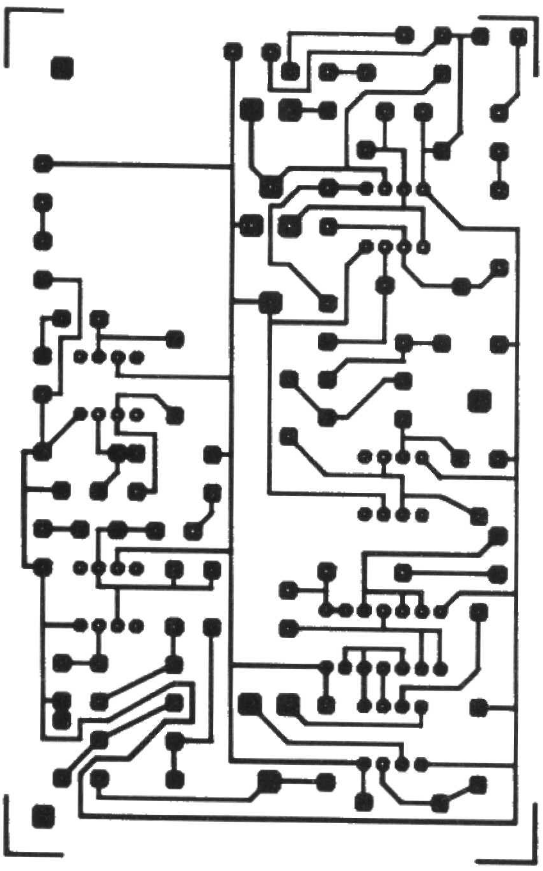

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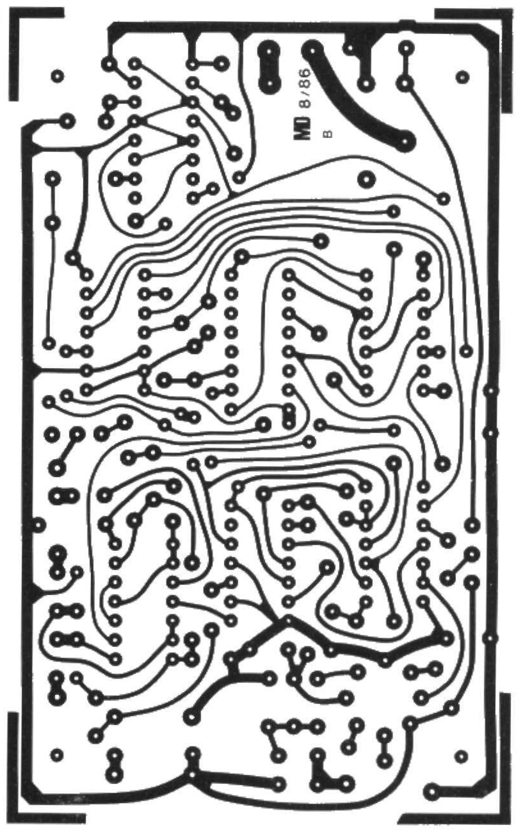

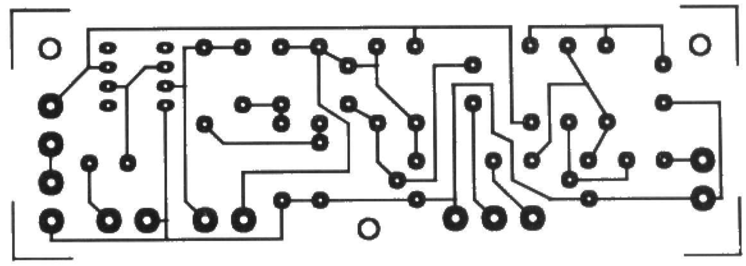

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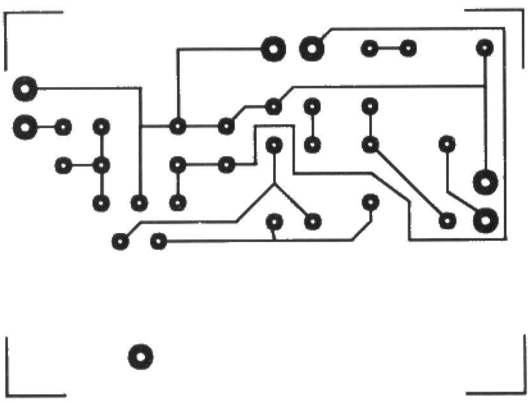

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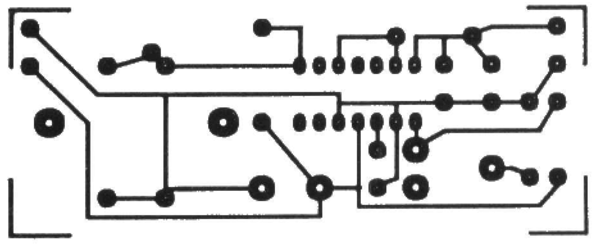

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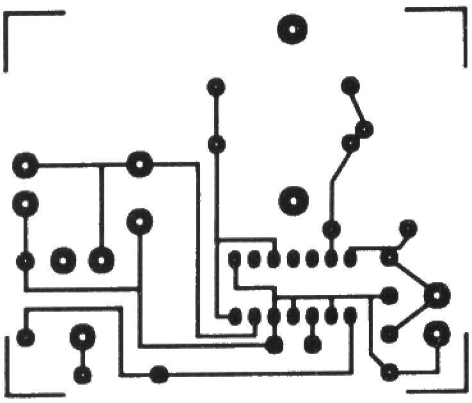

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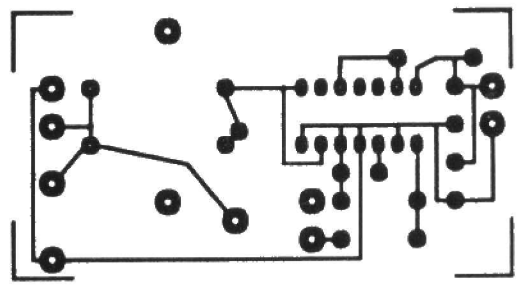

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20 A$=STR$(ABS(D>0))+A$:NEXTB:PRINT VAL(A$),:NEXTA:PRINT
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THREE SWITCH MODE POWER SUPPLIES

BY ROBERT PENFOLD

Up, down, inside – out

These three circuits, for a step down, booster and inverter type of power supply respectively, use the application – specific TL 497 i.c., whose operation is also described.

THE basics of switch mode power supply operation are covered in a separate article which can be found elsewhere in this issue. Here we will consider three practical designs for switch mode power supplies, one circuit for each of the three basic types (step-down, booster, and inverter). The idea is not to provide a high power multi-voltage supply which forms a project in its own right, but to provide some useful building blocks which the constructor can incorporate into his or her own designs.

There is some latitude as to the exact input and output voltages of the three designs, but the step-down regulator is intended to give a +5 volt output from a +12 volt input with a maximum output current of over 400 milliamps. The inverter is intended to provide a −5 volt output from a +5 volt output, and the maximum output current is about 150 milliamps. Finally, the booster yields an output of +12 volts from a +5 volt input, and the maximum output current is around 175 milliamps.

All three circuits are remarkably simple, and utilize the TL497 integrated circuit which is specifically designed for the present application. Unfortunately, switch mode regulator integrated circuits are considerably more expensive than conventional types such as the popular three and four terminal types, and they also need an inductor (which is also relatively expensive) in order to function properly. When deciding whether or not these modules are practical alternatives to more conventional designs this additional cost has to be weighed against the advantages of switch mode designs, and it will often not be possible to justify their use on economic grounds. However, under some circumstances switch mode power supplies are a very practical choice, and they also give added interest value to any project in which they are used.

TL497 BASICS

As all three circuits are based on the TL497 it would be as well to consider this device in some detail before progressing to a description of the power supply circuits themselves. The block diagram of Fig.1 shows the internal arrangement and pinout details for the TL497.

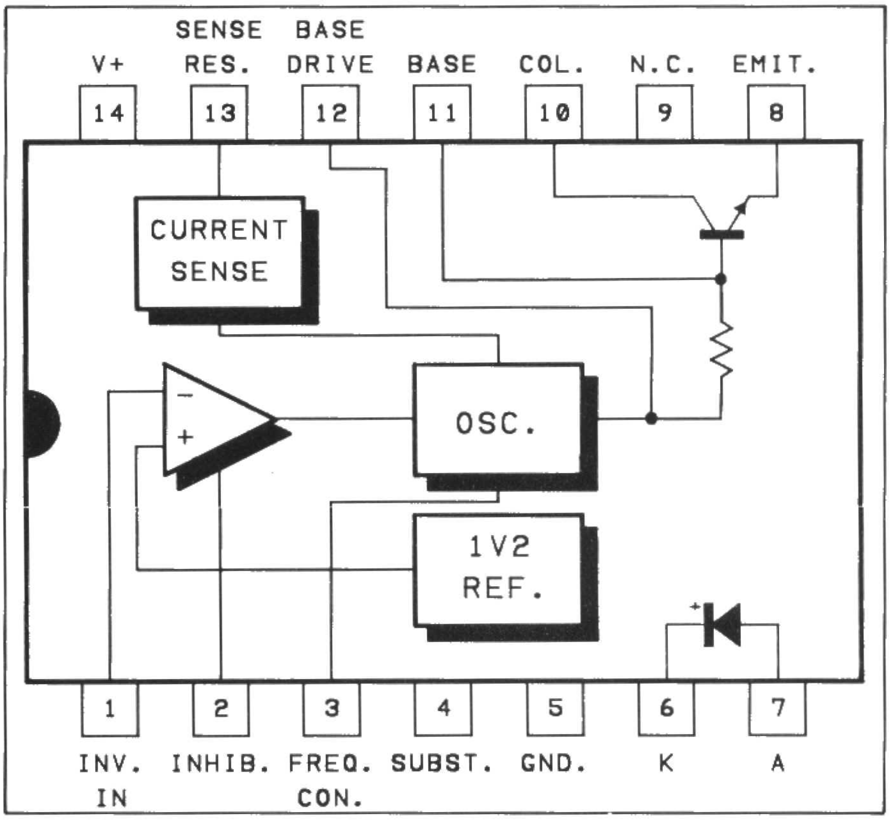


Fig.1. *TL 497 internal arrangement and pinout details.*

There is a rectifier available across pins 6 and 7 for use in the output stage, but note that the chip manufacturer recommends that an external component (such as a 1N4001) should be used for inverting mode circuits. This is presumably due to the diode being taken several volts negative of the 0 volt supply rail in this mode, and consequent problems with parasitic transistors or something of this ilk.

There is an internal reference voltage generator which has a nominal output potential of 1.2 volts, an actual output voltage which is graranteed to be not less than 1.08 volts and not greater than 1.32 volts. This voltage is not available externally, but is connected internally to the non-inverting input of the differential amplifier which acts as the error amplifier. The inverting input of the amplifier is made available at pin 1 so that it can be fed from a negative feedback network.

A current sensing circuit is built-in, and is used to reduce the output frequency in order to limit the input current to a preset level. Note that it is the input current and not the output current that is limited. Obviously by limiting the input current the output current is also prevented from exceeding a certain figure. However, unlike an ordinary series regulator where there is normally

little difference between the input and output currents, with a switching regulator there can be (and often is) a considerable difference between the two. This point is something that has to be kept firmly in mind, as does the fact that the maximum input current is 500 milliamps, but the maximum available output current is not necessarily as high as this. The input current limit value is set by a discrete resistor connected between pins 13 and 14, and the value of this resistor is equal to 0.5 divided by the required maximum input current. It is, of course, the peak input current that this resistor is determining, and not the average value.

The oscillator is a type which has a fixed "high" output period, and the average output voltage is varied by altering the frequency, which is effectively achieved by varying the "low" output period. The oscillator drives an output transistor which has its emitter and collector terminals unconnected and available at pins 8 and 10 respectively. This enables it to be used in any of the three standard types of output stage, but it can only handle output currents of up to 500 milliamps. For higher currents an external output stage is required, but in the circuits featured here the internal output stage suffices.

In operation the device is basically quite simple, and in some ways it is reminiscent of a relaxation oscillator. At switch-on the output voltage is zero, and this sends the output of the error amplifier fully positive so that a continuous stream of closely spaced pulses are produced by the oscillator. This quickly sends the output positive until it reaches the output voltage dictated by the feedback network. The output of the error amplifier then goes negative to reduce the average output voltage. If the output is loaded fairly heavily the circuit will settle down in standard pulse width modulation fashion to the point where the operating frequency of the oscillator is such that it maintains the required average output voltage. Things are rather different under very low loading, as the output filter and the load resistance have a relatively long time constant, and this tends to result in the output voltage building up to the point where the oscillator is cut off. Then, when the output voltage has subsided below its proper level, there is short burst of oscillation; the oscillator cuts off again, and so on. The output waveform is therefore short bursts of high frequency oscillations at a rate of perhaps only around 1Hz.

This may not seem to relate very well to classic pulse width modulation theory, since the average output voltage of the pulse signal and the smoothed output voltage are clearly not the same. The discrepancy is caused by the non-symmetrical nature of the output stage which effectively gives the smoothing circuit an attack time which is much longer than the decay time unless the load across the output evens things up. This is all largely of academic importance, of course, but it does mean that if you check the output waveforms using an oscilloscope, they may not be quite what you would expect from standard pulse width modulation theory.

R3 are the negative feedback network which determines the output voltage. it is convenient to have R3 at a value of 1k2 as the nominal output voltage is then equal to the total resistance of the feedback network in kilohms.

The output voltage can not be set very accurately using fixed value resistors due to the tolerance of the resistors and,

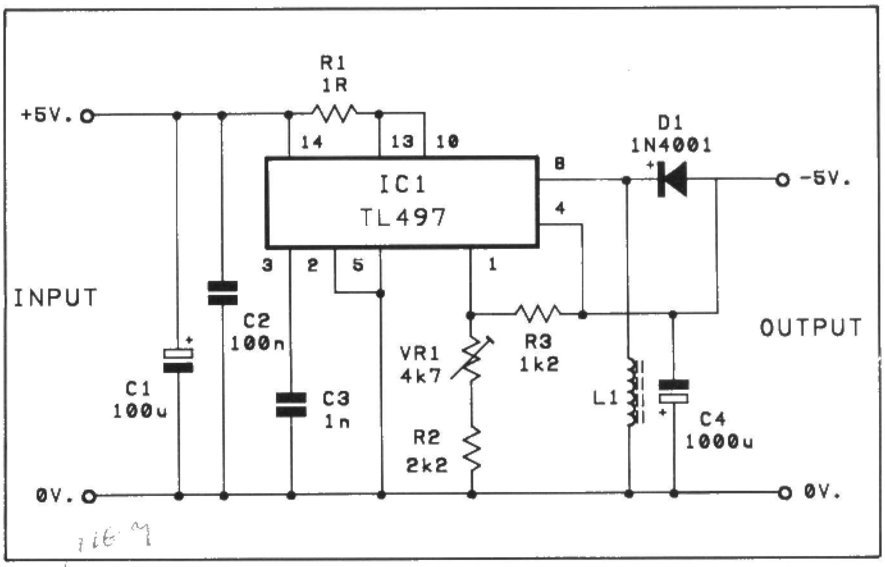


Fig.2. *The step-down regulator circuit diagram.*

STEP-DOWN CIRCUIT

The circuit diagram of the step-down regulator appears in Fig.2.

C1 and C2 provide input smoothing and decoupling, while R1 is the current limiting sense resistor. The latter sets the maximum input current at a nominal figure of 500 milliamps. As this is the peak input current rather than an average level it also limits the maximum output current at the same level in theory. In practice the circuit will not achieve 100% efficiency, and the maximum available output current will be, somewhat less, although still well over 400 milliamps. Of course, the average input current will be substantially less than the peak input current, except at very low output currents where the (typically) 11 milliamp current consumption of the TL497 and other losses seriously reduce the efficiency of the unit. On test the prototype had an input current of 115 milliamps from a 12 volt supply with the output voltage set at 5 volts and loaded to give an output current of 200 milliamps. This represents an input of 1.38 watts and an output of 1 watt, giving an efficiency of 72.5%. This compares with a figure of around 40% for a conventional series regulator used under the same conditions.

The output stage and rectifier of IC1 are connected in the standard step-down configuration, and L1 and C4 a conventional output filter. C3 is a timing capacitor for the oscillator, but it controls the "high" output pulse duration and not strictly speaking the output frequency of the oscillator. VR1, R2, and more particularly, the tolerance of the internal voltage reference. VR1 is therefore used to trim the output voltage to precisely 5 volts. The actual adjustment range is from around 3.4 volts at minimum resistance to around 8.1 volts at maximum resistance. If you require (say) a 6 volt output instead of a 5 volt type, this can be accommodated simply by adjusting VR1 for the appropriate output voltage.

Although the input voltage is given as 12 volts, this can be anything from about 3 volts more than the output voltage up to the 15 volt absolute maximum input voltage rating of the TL497. The unit does not need to be fed with a well stabilised and smoothed supply of course, and in practice it would often be better to feed it from a raw d.c. supply rather than via a regulator, so that it does not increase the loading on the regulator. However, this is only possible if the peak input voltage will not exceed 15 volts.

There is a TTL compatible inhibit input at pin 2 of IC1, but this is not used in the circuits described here, and in each case it is tied to the 0 volt supply rail. In all three circuits there is a risk of relatively strong high frequency noise spikes on the output due to the lower efficiency of the output filter capacitor at these frequencies. These will often be of no consequence, or will be eliminated by decoupling capacitors in the main circuit anyway, but if necessary they can be removed by connecting a ceramic capacitor of about 10n across the supply output.

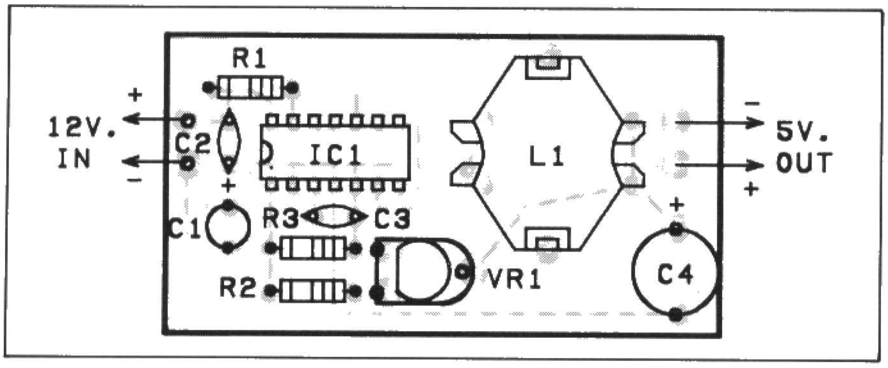


Fig.3. *PCB layout for the step-down regulator*

CONSTRUCTION

In common with the other two power supply designs featured here there is little difficulty as far as construction is concerned, and few components are used in any of the circuits. A suitable printed circuit design for the step-down regulator appears in Fig.3.

There is one slight problem in the form of inductor L1 which requires a value of a few hundred microhenries, but which must be a type that will work efficiently at the fre-quencies and currents involved here. The usual type of inductor for an application of this type is one based on a ferrite pot core, and although suitable ready made components do not seem to be available, it is not difficult to produce a suitable home wound component.

I used a pot core type RM8 having an inductance factor of 4100. A pair of cores is required, but they are normally sold as such. A bobbin is also needed, and this must be the correct 5 pin type if it is to fit onto the printed circuit board properly. A pair of mounting clamps are also needed, and these are normally sold singly. The winding consists of 30½ turns of 22 s.w.g. enamelled copper wire, and a 2oz reel of wire is sufficient to produce a number of these inductors.

Start by stripping about 3 millimetres of enamel insulation from the end of the wire (which may be easier using a sharp knife instead of wire strippers) and then tin the end of the wire and the top of one of the pins on the bobbin with solder. There should then by no problem in connecting these two together, after which the wire is taken in through the slit in the base of the bobbin so that the 30½ turns can be wound around it. There is no need to make the winding particularly neat, but do try to keep the wire fairly tight. In fact the whole assembly must be fixed together as tightly as possible and firmly held down on the board or the pulses of current through the inductor could result in a significant amount of noise being generated. When the correct number of turns have been added, take the wire out through the slit on the opposite side of the bobbin, cut it to length, strip the end of insulation, and connect it to a pin on that side of the bobbin. Note that the board has been designed so that it does not matter which two pins are used, with the only proviso that the two leadouts must connect to pins on opposite sides of the bobbin. The leads must both be connected right at the top of the pins so that the connections do not get in the way and prevent the finished assembly from fitting onto the board properly.

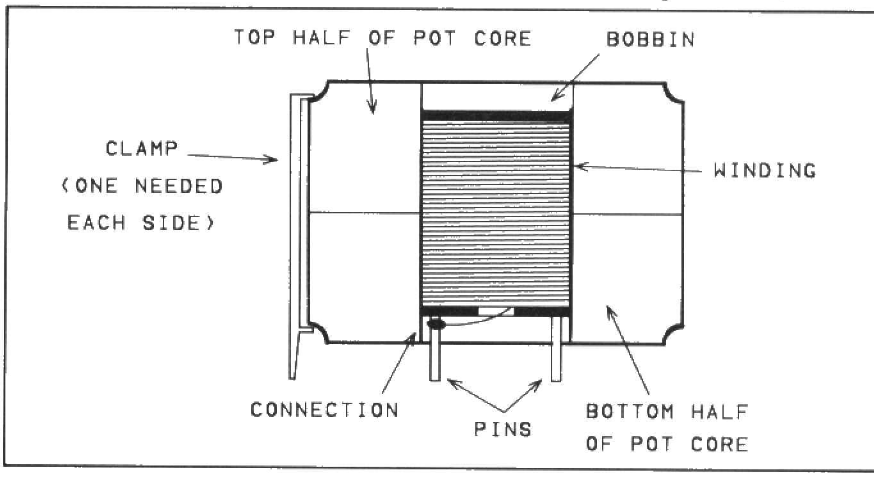


Fig.4. *The pot core assembly.*

To complete the unit the two halves of the core are placed in position and the two clamps are used to hold them together. They simply clip in place. The finished assembly should look something like the side view shown in Fig.4. Ferrite is not *quite* as brittle as egg shell, but it is not that much stronger. The finished inductor therefore needs to be treated with some respect and handled carefully. Dropping it onto a hard surface would almost certainly result in one of the cores smashing.

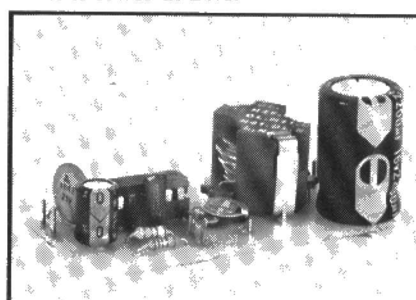
When first trying out this, or any of the designs featured in this article, it is advisable to include a multimeter (set to a d.c. current range with a full scale value of about 100 milliamps) in series with the input so that the input current can be monitored. With no loading on the output this should initially give a high reading which should almost immediately drop back to a reading of around 12 milliamps. The multimeter can then be set to a low d.c. voltage scale and connected across the output so that VR1 can be trimmed to give the correct output voltage.

BOOSTER CIRCUIT

The booster regulator circuit appears in Fig.5. This will not be described in detail as it basically just the step-down dircuit with the output stage revamped into the standard booster configuration. Also, the negative feedback network has been modified to give an output adjustment range of approximately 5.9 to 15.9 volts so that the required 12 volt output level can be accommodated. The circuit actually seems to work quite well with any output voltage within this range. Although the TL497 is limited to an input potential of 15 volts, it can handle output voltages of up to 35 volts; this is not to say that output voltages of around 30 volts are necessarily a practical proposition as the input voltage and inductor may not be adequate to support them.

The circuit provides a voltage boost, but at the expense of a current step-down. Therefore the output current will be less than the input current, and with the latter set at about 500 milliamps the theoretical maximum output current is just over 208 milliamps. In practice there are losses in the circuit which reduce efficiency and diminish the maximum output current. Around 170 to 180 milliamps shoud be available.

Construction of the unit is along similar lines to that of the step-down circuit, and the printed circuit design for the booster unit is given in Fig.6. The inductor is virtually the same as in the step-down circuit, but the number of turns is lower at 24½.



Step-down regulator

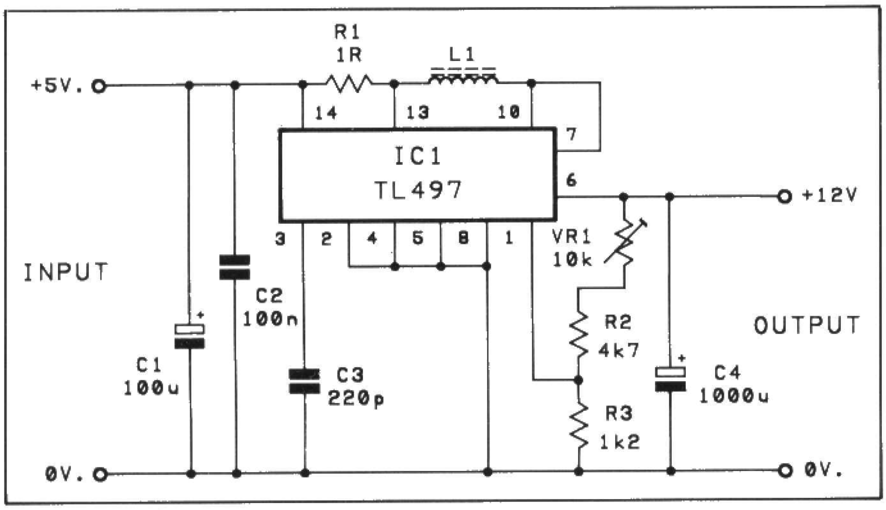


Fig.5. *Circuit diagram of the booster regulator.*

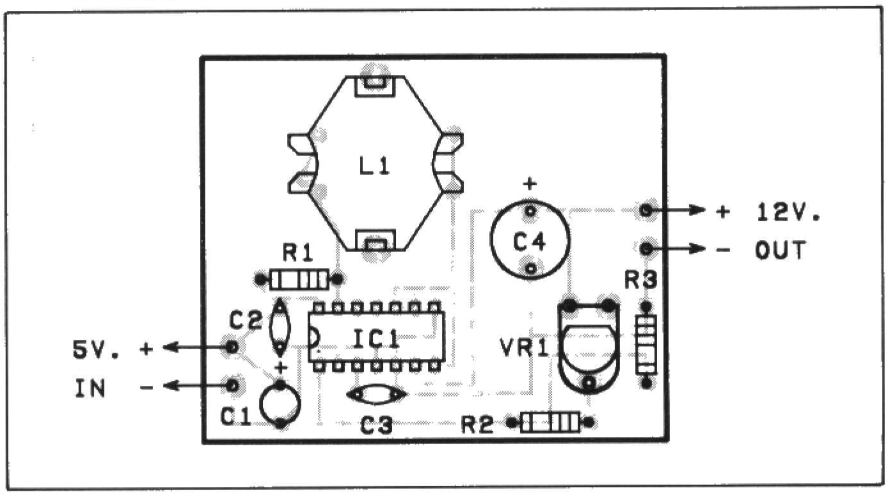


Fig.6. *PCB layout for the booster regulator*

INVERTER CIRCUIT

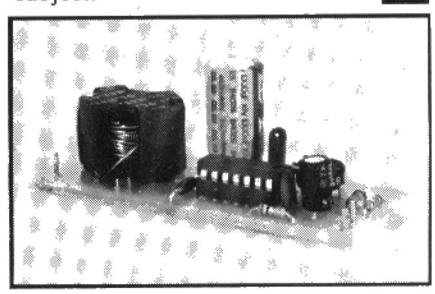
The circuit diagram for the inverter regulator appears in Fig.7, and this is again much the same as the step-down regulator but with the output stage re-arranged into the standard inverter configuration. There are a few other minor changes, one of which is the connection of IC1's substrate terminal (pin 4) to the output of the circuit. The negative feedback network also has to be altered in order to take account of the fact that the output is negative of the earth rail. With the substrate connected to the output, the voltage reference provides a voltage that is nominally 1.2 volts positive of the negative output rail, and in effect this rail becomes the earth rail to which all voltages are referenced as far as the stabilisation process is concerned. Therefore, the 1k2 resistor (R3) connects between the inverting input and the 0 volt rail (which is effectively the positive output rail as far as the regulator circuits are concerned). This gives what is essentially the same negative feedback and stabilisation process as in the previous circuits, with the nominal output voltage again being equal to the total feedback resistance in kilohms.

Construction of the unit is much the same as for the other two circuits, and details of the printed circuit board are provided in Fig.8. Note that in this circuit L1 only requires 18½ turns.

Despite a fair amount of experimentation with this circuit I never managed to coax particularly high output currents from it, and an output of about 150 milliamps represent about the maximum that can be expected. On the other hand, this compares well with circuits based on the popular ICL7660 which give an output of under 5 volts even with quite modest loading on the output, and would not normally be used for output currents of more than about 10 milliamps. This circuit will give about 150 milliamps without any significant loading of the output below its nominal –5 volt level. Efficiency of the circuit was also disappointing at only about 50%, although this is quite reasonable by general power supply standards and is certainly perfectly usable. As with the previous circuits, there is some latitude as to the exact input and output voltages, and the unit will, for example, generate a –5 volt output from a +12 volt input (provided C1 is changed to a 16V type). In fact it seems to perate more efficiently when operated in this way, offering an efficiency of around 75% and a maximum output current of approximately 400 milliamps.

CONCLUSION

These circuits all represent useful electronic building blocks which are well worth considering for inclusion in a project that has unusual or awkward power supply requirements. They also represent interesting projects to experiment with if you are new to switch mode power supplies, and they given an easy and inexpensive introduction to the subject. PE



Inverter regulator

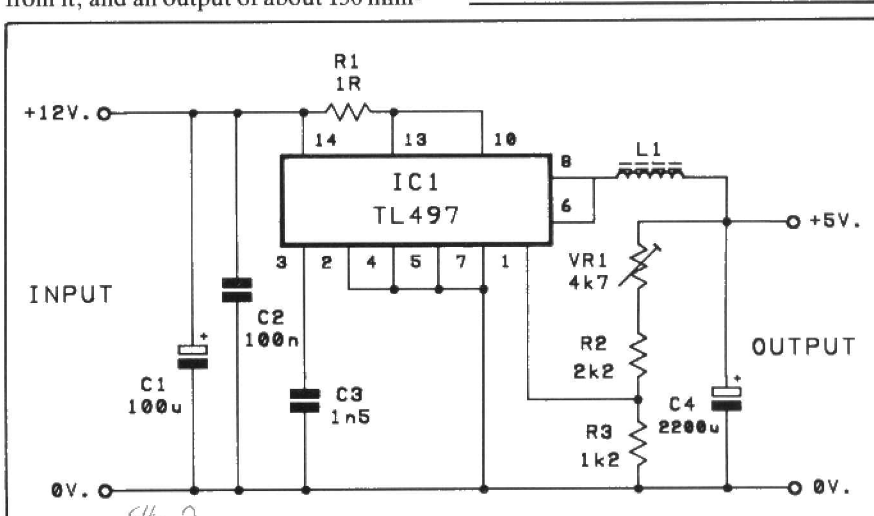


Fig.7. *The inverter regulator circuit diagram.*

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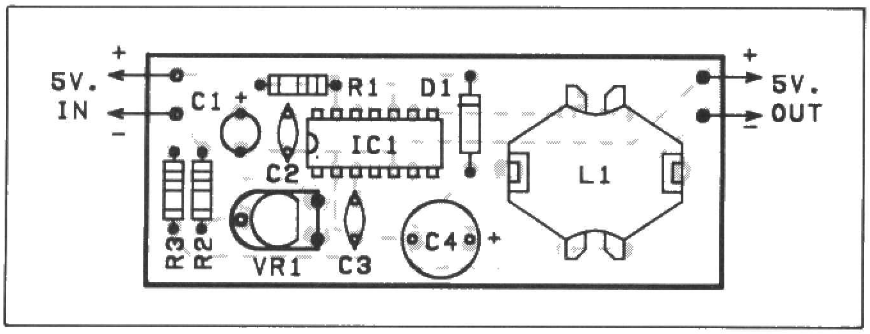


Fig.8. *The inverter PCB layout*

BOOSTER

RESISTORS
R1 1_R
R2 4k7
R3 1k2
All resistors ⅓ watt 5% carbon

POTENTIOMETER
VR1 10k sub-min hor. preset

CAPACITOR
C1 100μ 10V radial elect
C2 100n ceramic
C3 220p ceramic plate
C4 100μ 16V radial elect

SEMICONDUCTOR
IC1 TL497

STEP-DOWN REGULATOR

RESISTORS
R1 1_R
R2 2k2
R3 1k2
All resistors ⅓ watt 5% carbon

POTENTIOMETER
VR1 4k7 sub-min hor. preset

CAPACITORS
C1 100μ 16V radial elect
C2 100n ceramic
C3 1n5 mylar
C4 2200μ 10V radial elect

SEMICONDUCTOR
IC1 TL497

INVERTER

RESISTORS
R1 1_R
R2 2k2
R3 1k2
All resistors ⅓ watt 5% carbon

POTENTIOMETER
VR1 4k7 sub-min hor. preset

CAPACITORS
C1 100μ 10V radial elect
C2 100n ceramic
C3 1n mylar
C4 100μ 10V radial elect

SEMICONDUCTORS
IC1 TL497
D1 1N4001

MISCELLANEOUS
(Common to all circuits)
L1, LM8 pot core type B65811 J0000R041, former type B65812 A1005 D001, clamp B65812 A2203 (2 off), 22 s.w.g. enamelled copper wire, printed circuit board, 14 pin DIL i.c. socket, pins, solder, etc.

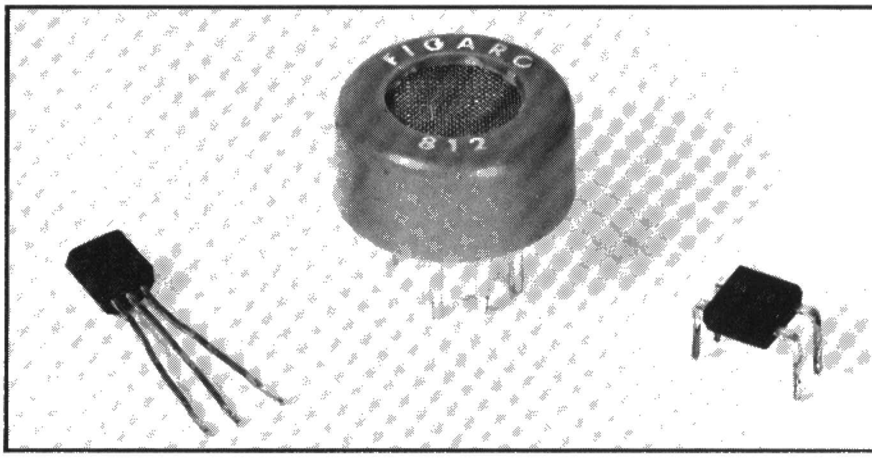
SENSORS

PART ONE BY THE PROF

Translating the environment into control signals

Sensors are an essential stage in translating non-electrical signals into a form which electronics can detect and control. Part one of a two-part article looks at the Hall effect, gas and light sensors, and strain gauges.

ONE of the biggest growth areas of electronics in recent years has been measurement and control, and with it a whole range of electronic sensors has become available. It now seems to be possible to measure electronically practically anything that can be quantitized, and to detect virtually any substance or form of energy. Sensors vary in complexity from simple mechanical devices such as micro-switches to complex semiconductor devices. In an article such as this it is only possible to scratch the surface of this subject, and we will mainly be concerned with the types of sensor which are available to the amateur user who wishes to experiment with them, but which are rarely (if ever) featured in constructional articles. It is not possible to give practical circuits using the devices covered, and only the fundamentals of their operation and the basic way in which they are used will be covered, but some of the sensors may be featured in practical projects in future issues.



Hall effect switch, Figaro 812 gas sensor and Linear Hall Effect Sensor.

HALL EFFECT

Sensors which take advantage of the Hall effect might have few obvious practical applications, but they are certainly amongst the most interesting of components, and while not dirt cheap, are far from the most expensive of devices. They are designed to detect magnetic fields, and apart from the obvious application of magnetic field strength measurement, Hall effect devices are often used as "noiseless" switches in conjunction with an actuating magnet. In fact most Hall effect devices seem to be of the switching type rather than linear sensors.

The general idea of a Hall effect switch is to have a keyboard fitted with keys that contain magnets, with a sensor mounted under each switch. When a key is operated the magnet within it is brought close to the corresponding Hall effect sensor which is consequently activated, and its output changes state. There is no contact bounce with this arrangement, although spurious signals could still be produced if a key was not operated properly and was not fully depressed. The sensor therefore incorporates a certain amount of hysteresis so that it is almost impossible to produce spurious output pulses.

This approach may seem rather like "taking a sledgehammer to crack a nut", and it is a comparatively expensive way of doing things. Apart from the "noiseless" aspect, the lack of any switch contacts gives a long operating life and excellent reliability which can justify the extra expense in the more demanding of applications. Hall effect switches are not only suitable for keyboard purposes, and they are apt to a whole range of switching applications. In particular they are excellent for use in situations where reed switches would normally be utilised, which includes such things as door and window switches in burglar alarm systems, and train detectors in model railway layouts.

So just what is the Hall effect, and how does a Hall sensor operate? Fig.1 helps to explain the way in which these devices function, and in Fig.1(a) we have a thin slice of silicon with two electrodes fitted on opposite sides, but otherwise at the same point on the slice. A current is passed through the silicon slice, and this gives a potential gradient which ranges from 0 volts at the bottom of the slice to the full input voltage at the top. The electrodes are about half way up the slice, and about half the input voltage appears at each one. The exact voltage is not important, and the salient point here is that the same voltage will be present at each electrode, giving a differential output voltage of zero.

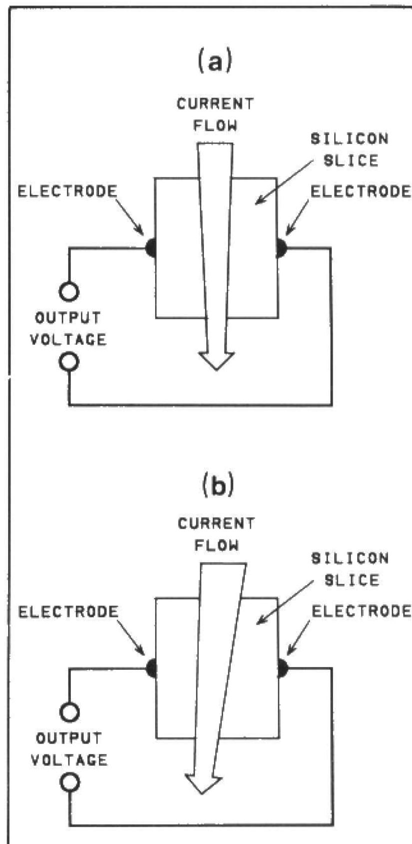


Fig.1. *(a) Normal current flow through semi-conductor material, and (b) the effect of a suitable magnetic field on the current flow.*

In Fig.1(b) a magnetic field has been introduced, and this is perpendicular to the direction of the current flow. The result is a deflection of the current carriers, rather like a magnetic field deflecting the electron beam of a cathode ray tube. This results in a distortion of the potential gradient, and with this distortion in the direction shown in Fig.1(b), this results in the voltage at one electrode increasing and the voltage at the other electrode decreasing. This gives a voltage difference across the electrodes,and the stronger the magnetic field, the larger the differential output voltage. If the polarity of the magnetic field is reversed, so is the polarity of the output signal, and this the factor which is exploited in some practical devices.

An important point to bear in mind when using Hall effect devices, is that they will only respond properly to a magnetic field in the correct direction, and that a field at right angles to this direction gives no output signal whatever.

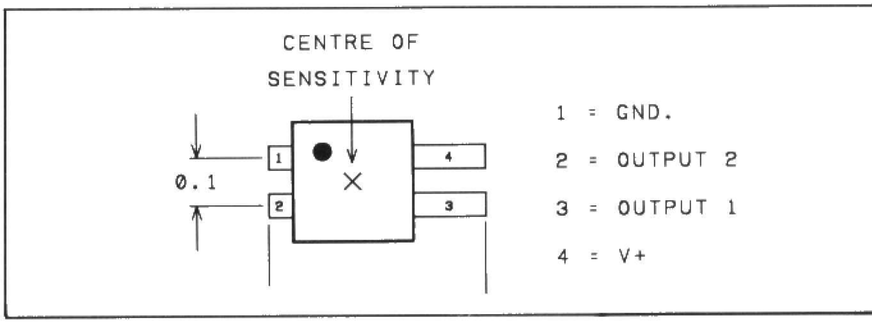


Fig.3. *Pinout details for the 634SS2 linear Hall effect device.*

the two outputs available via buffer amplifiers. The 634SS2 is an example of a device of this type, and Fig.3 gives pinout and basic physical details of this component. It operates in the circuit shown in Fig.4, and it only needs two load resistors and a supply voltage of between 4 and 10 volts. Note that although differential outputs are available, it is not essential to use both of them, and in non-critical applications it would be quite acceptable to use a single output.

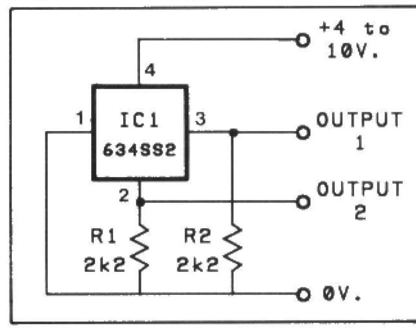


Fig.4. *Basic circuit for the 634SS2*

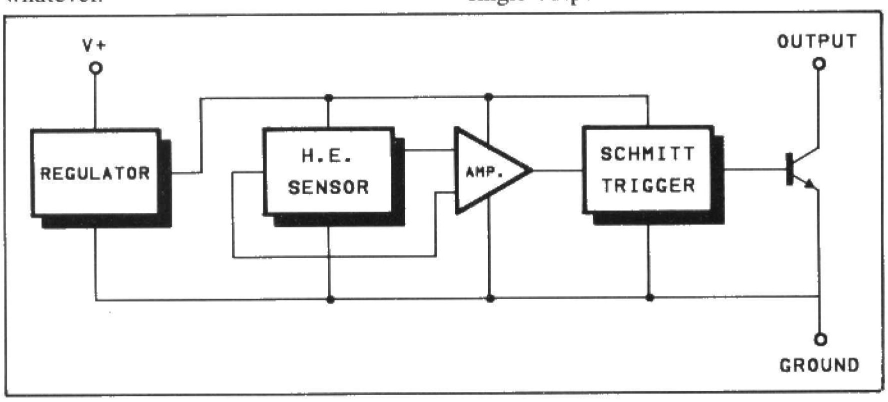


Fig.2. *Typical arrangement for a Hall effect switching device.*

Practical Hall effect devices are generally more than just the sensor itself, and a typical device would have an internal arrangement of the type shown in Fig.2 (which is actually the arrangement used in the RS 307-446 device). There is an internal voltage regulator to ensure consistent results from the component, and this provides power to all stages. The output from the Hall effect sensor is fed to a differential amplifier, and when the device is activated this provides sufficient output to operate a Schmitt trigger. The latter then switches on an npn transister which has an open collector output which can be used to drive a logic input, or to operate directly a small load such as a l.e.d. indicator or a small relay.

This arrangement is by no means universal, and there are alternative types, including one which latches in the "on" state, and which can only be switched off by briefly cutting off the power to the device, or applying a reverse magnetic field. Another type, and one which is interesting to experimrny with, is the linear type. This is basically just a Hall effect sensor with

A device of this type can be used in magnetic field strength measuring equipment, and the sensitivity of the 634SS2 is between 0.75 and 1.06 millivolts per gauss. It has reasonable linearity from −400 to +400 gauss. Linear hall effect sensors can also be used in linear applications where "noiseless" operation is required, such as in Hall effect swell pedals where the volume of an electric or electronic musical instrument is varied by a foot pedal. Instead of having the pedal mechanism operate an ordinary potentiometer, it simply moves a magnet towards or away from a linear Hall effect device, which via suitable electronics controls a voltage controlled attenuator. With no potentiometer track to wear or become dirty, this arrangement gives good results and excellent reliability.

Perhaps the obvious application for a linear Hall effect device is in the playback head of a tape recorder, and I believe such a unit was produced some years ago. However, this type of playback head does not seem to have become established, and it is presumably not a cost effective alternative to conventional types. At a simpler level I once tried a linear Hall effect device in a cable locator of the type designed to pick up the magnetic "hum" radiated by mains cable which is passing an electric current. This was completely unsuccessful due to a gross lack of sensitivity, and the output from a Hall effect sensor would seem to be far lower than that from an inductive sensor. However, whereas a simple inductive sensor will detect only a varying field, a Hall type will detect a field of constant strength, which can be crucial in some applications.

IN VANE

There is a type of Hall effect switch that is intended for counting applications of the type where a slotted opto sensor would normally be used, but is unsuitable due to excessive ambient light or high dust levels. These devices are called Hall effect vane switches, and they are really just a bar magnet and an ordinary Hall effect switch combined in a single printed circuit mounting component. The magnet is just too far away from the Hall effect switch to activate it, but if a piece of ferrous metal (the "vane") is placed in the gap, it effectively extends the magnet and activates the switch. Of course, a sensor of this type is only suitable for operation with ferrous metals, unlike slotted optical sensors.They are capable of quite high speed operation, with a maximum of about 100kHZ being typical.

GAS SENSORS

There are several ways of detecting gas or smoke, and the simplest types are photoelectric devices intended only for smoke detection. These take the general

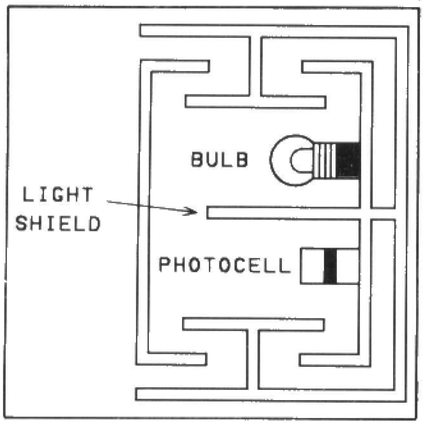


Fig.5. *A low tech form of smoke detector*

form outlined in Fig.5, and they are very straightforward in operation. The general idea is for the box to be constructed in a way that allows smoke to enter and leave, but which blocks a significant amount of light from entering. The case is painted mat black on the inside so that only an insignificant amount of light normally reaches the photocell from the light source. An ordinary filament bulb is preferable to a light emitting diode in this case, as it will generate more heat and will consequently encourage a flow of air through the box. This helps to draw in any smoke in the air surrounding the unit. If any smoke should be drawn into the case, it will tend to reflect light from the lamp onto the photocell, and with suitable circuitry, this increased light level can be detected and used to trigger an alarm.

This is not the only possible type of photoelectric smoke detector, and there are similar systems which have the light source aimed at the photocell, and rely on the smoke to vary the light intensity received by the photocell. These days there are more sophisticated types of smoke sensor available, including types which will detect practically any inflammable gas or vapour, even when they are only present in highly diluted form. The "Figaro" 812 and 813 gas detectors have been featured in constructional projects in the past, and these have a semiconductor sensing element. The element is heated by an ordinary filament type heater, and it oxidizes the semiconductor element which consequently exhibits a fairly high resistance (typically around 100k or more). Suitable gasses have a reducing (deoxidizing) effect on the element, which results in its resistance falling quite dramatically, and even quite weak concentrations of gas are sufficient to cause the resistance to drop to just a few kilohms.

There is an alternative type which is less widely used in home constructor designs (but which is available to amateur users in the form of the RS 307-733 sensor). This has two platinum wire elements which are heated, and one of which is coated with the special sensing materials. The uncoated element is needed to compensate for changes in temperature and humidity, and devices of this type are generally used in a bridge circuit of the type shown in Fig.6. Normally the two resistances provided by the sensor are equal, and half the supply voltage is fed to the relevant input of the voltage comparator. R1, R2, and VR1 provide an adjustable reference voltage to the other input of the comparator. VR1 is adjusted to provide a voltage that is just above or below half the supply voltage, so that under stand-by conditions the output of the comparator is sent high or low, as required. Any drift in the resistance of one section of the element should be matched by a similar change in the resistance of the other section, so that the output from the sensor remains unchanged.

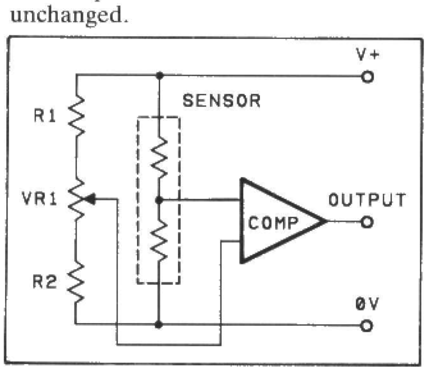


Fig.6. *Basic circuit for using platinum wire gas sensors.*

In operation, this type of sensor is essentially the same as the semiconductor type, and uses what is apparently called the "pellistor" principle. There is a fundamental difference between the two types in that the semiconductor type has separate heating elements, whereas with the platinum wire type the two wires act as both the heating and sensing elements. Both types are capable of detecting gasses such as butane and methane, and at concentrations that are well below the explosive threshold. Of course, this still leaves a danger of the heating elements igniting the detected gasses if they should be allowed to continue to build up after detection, and to avoid this the elements are shielded by double wire netting. The platinum wire devices have good linearity and are suitable for measurement applications as well as operation in simple detection circuits. However, both types of sensor are more sensitive to some gasses than they are to others, and the scaling would need to be for a specific gas.

LIGHT SENSORS

There is no shortage of devices for the detection of light, and most readers will probably be familiar with cadmium sulphide photo-resistors, such as the ORP12, and various semiconductor light sensitive devices. For simple switching applications and the like, the choice of device is generally not too critical, except where high operating speed is required. Photo-diodes are then the normal choice, although the price that has to be paid for the relatively fast response time is a rather low level of sensitivity. Cadmium sulphide photo-resistors and photo-darlington devices offer very high levels of sensitivity, but are extremely slow, particularly some of the larger cadmium sulphide devices which can take several seconds to adjust to changes from very bright to very dark conditions.

Cadmium sulphide cells usually have a zigzag track of this material (which is clearly visible through its transparent protective covering), which is deposited on an insulating substrate, and they rely on the fact that the resistance of cadmium sulphide decreases as the light level is increased. Although regarded by many as completely out of date, there are many non-critical applications where this type of cell represents the most suitable choice. Their biggest selling point is undoubtedly their extremely high sensitivity, and the humble ORP12 type for example, has a resistance that can be just a few tens of ohms under extremely bright conditions, but which can rise to over 10 megohms when the component is subjected to total darkness. This represents a change in resistance by a factor of more than 100000, and is acheived without any form of amplification.

Where light measurement is required, and linear scaling is normally called for, a photo-diode is the usual choice of sensor. There is not really a great deal of difference between an ordinary semiconductor device and its photo-sensitive equivalent. Semiconductor devices are naturally light sensitive, but are normally housed in opaque encapsulations, to avoid changes in light level affecting their performance. With the photo-sensitive devices the semiconductor material is mounted beneath a window (or often a simple lens in fact), so that light can reach it. Those who can remember electronics construction in the 1960s may recall the old ploy of scraping off the paint from an OC71 transistor (with its glass casing) to effectively turn it into an OCP71 photo-transistor, but at a fraction of the cost of a genuine OCP71. A trick that worked well until an opaque filling was introduced between the semiconductor and the glass casing.

Photo-diodes can be used as photo-voltaic cells (i.e. to generate a voltage in the presence of light), but they are more usually operated in the reverse biased mode. This gives a slightly higher level of sensitivity, although compared with most other photocells, photo-diodes are very insensitive in either mode. Under darkness the diode has the

normal low reverse leakage level associated with a silicon diode, but under bright conditions a somewhat higher leakage current flows. When operated in the reverse biased mode, there is a linear relationship between light level and output current over a wide range of light levels.

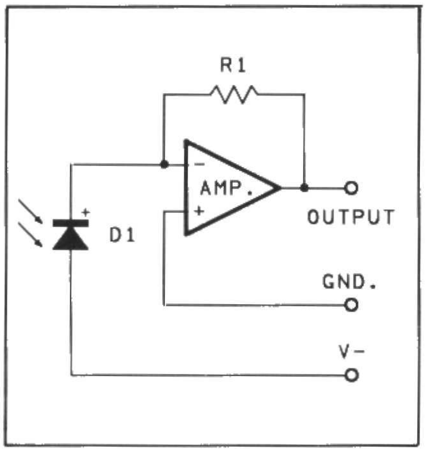


Fig.7. *Using a photo-diode in a measuring circuit which has a linear response.*

When photo-diodes are used in measuring applications they are normally operated in the basic configuration shown in Fig.7 This is similar to the standard operational amplifier inverting mode, with the obvious exception that there is no input resistor and the photo-diode feeds direct into the inverting input of the operational amplifier. Operation of the circuit is essentially the same as for an ordinary inverting amplifier though, with D1 leaking a current into the negative supply rail. In order to maintain equilibrium at the two inputs of the operational amplifier, the output must swing positive. The output goes positive by an amount which drives a current through R1 that exactly matches the current flow through D1. The circuit thus gives a simple current to voltage conversion, and the higher the value of R1, the greater the output voltage that a given input current will produce.

Apart from straightforward light measuring applications, a circuit of this type can form the basis of more exotic circuits such as flash-meters. These usually have an integrator which is used in such a way that the final reading takes into account both the intensity of the light pulse and its duration (both of which affect the exposure value). The high speed of photo-diodes is important in this application, and most types can respond to large changes in light level in under a microsecond.

TAKING THE STRAIN

Strain gauges seem to feature little (if at all) in home constructor projects, but are one of the most common types of sensor. They are used in the testing of mechanical structures, including such things as aeroplane wings, bridges, and buildings. In fact they are used to test practically every structure where physical strength and long term reliability are of importance.

Modern strain gauges are usually formed using a photo-etching process, and they consist of a grid of fine wire which is normally contained in a protective coating of polyester. The latter also serves as a medium to couple the strain from the test material to the gauge itself. The wire is often made from a copper-nickel alloy which has a very low temperature coefficient, so that changes in temperature have a very small (and predictable) effect on the resistance through the component.

The sensor gives a change in resistance when it is flexed, due primarily to stretching, or compression of the wire. Apart from altering the length of the wire, this also changes its cross section, and both factors produce a change in resistance. There is another factor which contributes to the variation in resistance, and this is the change in the structure of the material, but this second influence is generally a relatively minor one.

In order to work properly, a strain gauge must be properly fixed to the surface which is being monitored, and this normally means gluing it in place with a high quality adhesive. An epoxy resin type is suitable, and the layer of adhesive must be kept very thin, so that it does not absorb a significant amount of the strain. The surface to which the gauge is fixed must be carefully prepared so that the adhesive sticks to it properly over the entire area covered by the gauge.

Strain gauges are normally operated in some form of bridge or pseudo bridge circuit, and the basic type is the quarter-bridge type shown in Fig.8(a). R1 and the gauge form a potential divider across the supply lines, and the output voltage varies slightly in sympathy with changes in the resistance of the gauge. R2 and R3 provide a reference voltage which offsets the quiescent output voltage from the other half of the bridge, so that the output voltage from the circuit as a whole is equal to the change in voltage when the gauge is stressed. Normally the output signal would be coupled to a high gain differential amplifier in order to boost the signal to a useful level. As the amplifier has to be d.c. coupled, and only small input voltage changes are involved, the resistors must be high quality types. Also, the operational amplifier used as the basis of the differential amplifier, must be a special low drift type – the humble 741C is not suitable for a demanding application of this type.

In some applications, particularly those in which compression is being sensed, strain gauges are used in all four arms of the bridge. This gives the so called full bridge circuit of Fig.8(b).

For those who like to experiment with such things, a useful range of strain gauges are available through RS stockists. PE

NEXT MONTH:
PARTTWO WILL DISCUSS THERMISTORS, THERMOCOUPLES, PYRO DETECTORS, AND pH PROBES.

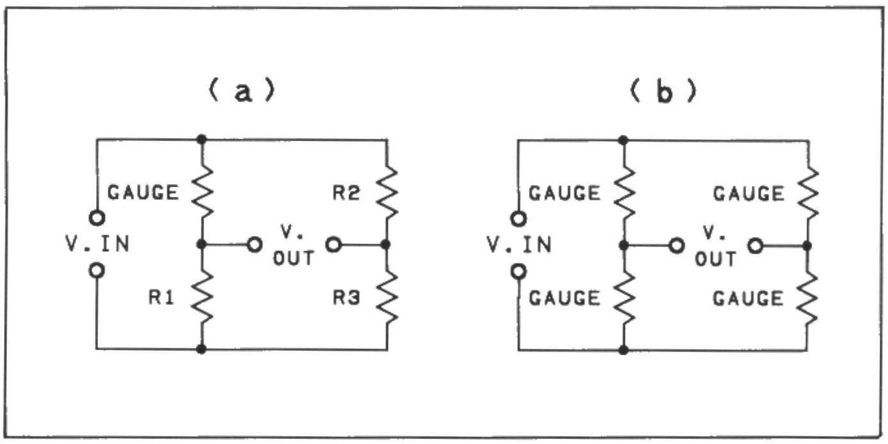
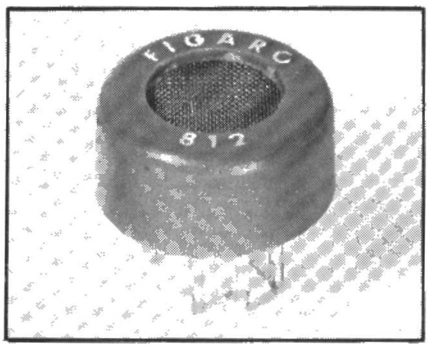


Fig.8. *(a) The quarter bridge measuring circuit and (b) the full bridge type.*

Each gauge has what is termed a "gauge factor" ("K"), which is effectively a measure of its sensitivity. The gauge factor is given by the formula: $K \times r/R.E.$ Where r is the change in resistance caused by applying strain E, and R is the resistance of the gauge with no stress applied. The higher the gauge factor, the greater the change in resistance for a given degree of stress. Typically the strain factor is only about 2, and the resistance through the gauge is around a hundred ohms or so.



AMSTRAD EPROM PROGRAMMERS

STEPHEN BURKITT

Simple design, inexpensive parts

The Amstrad's versatile sidways ROM is ideal for interfacing to an Eprom programmer. The I/O port can be used as an alternative.

CIRCUIT 1

THE AMSTRAD has a versatile sideways ROM ability yet the availability of Eprom programmers has been virtually nil. One or two are now appearing on the market, but are still extremely expensive. I therefore set out to build an inexpensive unit which would cater for the majority of Eproms, yet remain very simple and use only commonly available items. In fact, the whole prototype was built from surplus chips from my junk box.

The circuit is simple, requiring only an external variable power supply for the programming voltage. This can be easily constructed using the common single chip regulators. Fig.1. shows the wiring of the unit. The prototype was built on Vero V-Q prototype board, but any suitable type will do. The main part of the circuit revolves around the INTEL 8255 peripheral chip. This is a versatile circuit which can be programmed to almost any configaration to suit. The main use requires the chip to be in mode 0 which gives three eight bit ports, with port A, O/P, (low address), port C, O/P, (high address), and port B, data (set to input for verify and output for program). This is done by setting the control register (&80 for output and &82 for input). Bits 6,7 of port C are used as the chip select and program pulse respectively. In order to allow for different Eproms a customised jumper is used. A 14 pin header plug is suitable for this. The program supplied gives details of connections for various

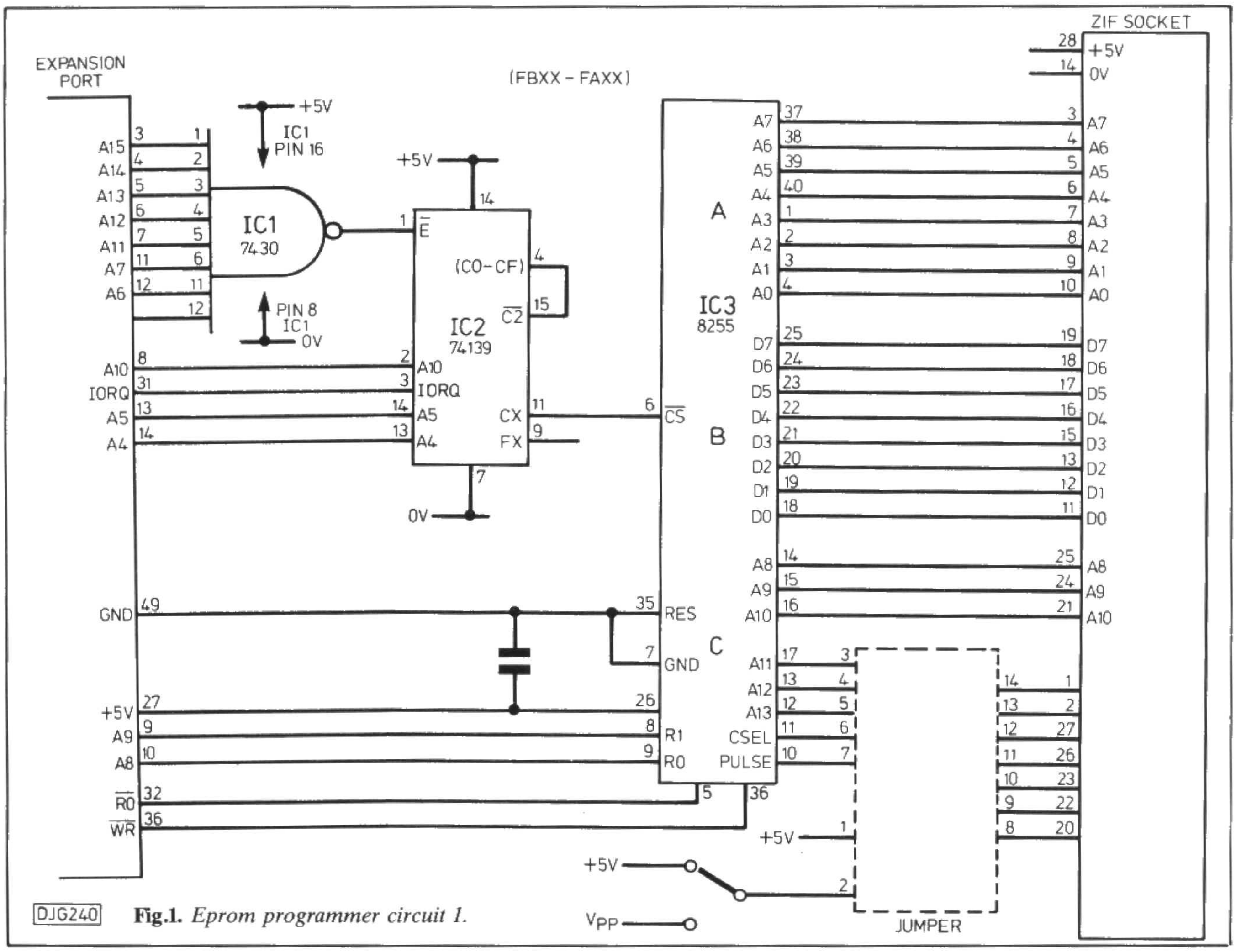


Fig.1. *Eprom programmer circuit 1.*

Eproms. Address decoding is simple but conforms to the Amstrad specification. IC1 and IC2 give an I/O port base address of &F8EO. Use of a ZIF socket is recommended, but by no means essential. No protection is incorporated for incorrect insertion of Eproms so care must be taken in use.

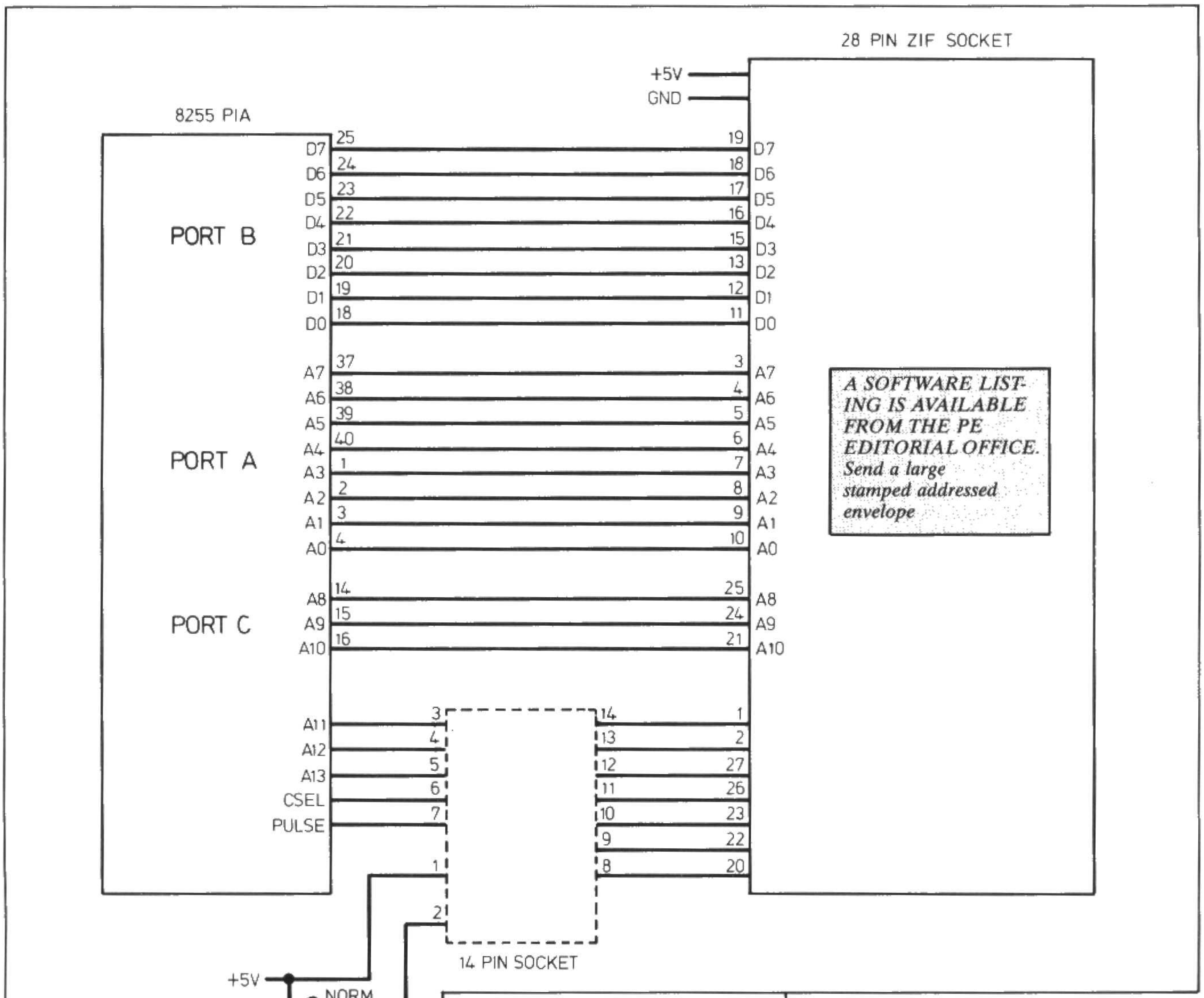
CIRCUIT 2

The Amstrad I/O port (PE March 86) provides the Amstrad machines with a versatile port facility. One use of this would be as an Eprom programmer which can easily be achieved with just a few extra components. Along with a sideways ROM circuit board, this will enable the avid programmer to transfer programs onto ROM for instant use. The Amstrad firmware manuals give details of ROM code layout.

Fig.2. gives details of a suitable addition to enable programming of Eproms from the basic 2716 to the 27128. The 27256 could be used with minor adaption. Software written in Basic was used as speed was not essential. The modular layout will enable easy translation to assembler code if required. An external low current variable power supply is required, and can easily be made using standard voltage regulator chips. A d.i.l. header is used to configure the p.c.b. for different Eproms. This may be left out if only one type will be used. Wiring for the jumper is displayed on the screen guide.

Programming consists of setting the required address and data on the Eprom input lines while the Eprom is pulsed for 50 milliseconds. This is achieved by a for/next loop, catering for each location. Users are advised to consult data sheets for each Eprom as pinouts and voltages may vary. The software allows loading and saving of data to a buffer at &4000 (16384), with printout to screen or printer as required. Locations may be set individually or in block. Bytes not required for programming must be set to &ff (255) if they are in the middle of the programming block. Eproms may only be erased by ultra-violet light.

The listing is adequately REM'ed for information on each module and on screen guideance is provided. Entry of addresses is in decimal, with confirmation in hexadecimal. Pressing Return will normally give default addresses of &4000 to &4000+ Eprom size. PE



A SOFTWARE LISTING IS AVAILABLE FROM THE PE EDITORIAL OFFICE. *Send a large stamped addressed envelope*

Fig.2. *Eprom programmer circuit 2.*

Construction is straight forward. Sockets are best used for all i.c.s., and decoupling capacitors fitted. The unit should be checked for shorts following assembly, and it is advisable to check voltages with the p.c.b. connected before finally fitting the I.c.s.

In order to allow for flexibility in development the software was written in Basic. Instructions on use are provided in the program. A buffer starting at 16384 (&4000) is used for the Eprom data, and is the default setting. A screen dump facility exists which can also be directed to a printer if required.

SPACEWATCH

BY DR PATRICK MOORE OBE

Our regular look at astronomy

Launches continue, despite American problems; and a major new microwave telescope is in operation on Mauna Kea.

MAGELLAN – The Venus Radar Mapper VRM, now officially renamed Magellan, has been given a definite launch date: 25 April 1989. This is a year behind schedule, due to the various delays in the American space programme – most notably, of course, the Challenger tragedy. However, Magellan will definitely be dispatched, and there is one advantage in the delay, inasmuch as full use can now be made of the data sent back by the orbiting Russian space-craft, Veneras 15 and 16. Venus is indeed a curious world; whether or not there is active vulcanism there is still a matter for debate, but most investigators believe that there is.

THE PHOBOS PROBE Another important launch date has also been announced. In July 1988 Russia's latest Mars probes will begin their journey. Up to now the Russians have had no success at all with Mars, though numerous space-craft have been sent to the Red Planet. This new venture is ambitious, since it will take in not only Mars but also its larger satelite, Phobos. To quote Dr. V. Balebanov, Deputy Director of the Space Research Institute of the USSR Academy of Sciences: "The two probes will thoroughly study the Martian surface, its atmosphere, ionosphere and magnetosphere. In January 1989 they will transmit television pictures of the planet, data about the chemical and mineralogical composition of the rocks, and their radiophysical characteristics." It is also hoped to solve the mysteries of the dust-storms. Dr. Balebanov's reference to the magnetosphere is interesting; up to now there are no indications that Mars has a magnetic field strong enough to be detectable – a lack which it shares with Venus and the Moon, but not with Mercury.

THE SPACE STATION – Despite all NASA's problems, financial and technical, it is still hoped to have a proper space-station in orbit well before the end of the 1990's. There has been one very encouraging sign: funding of 410,000,000 dollars has been guaranteed by Congress for the fiscal year 1987, with the enthusiastic support of President Reagan.

THE JAMES CLERK MAXWELL TELESCOPE

Until well into our own century, astronomers had to depend entirely upon visible light. Then, from the 1930s, radio astronomy joined in, to be followed by investigations into other regions of the electromagnetic spectrum – even down to the ultra-short gamma-rays. Most of this work has to be carried out from space. However, there is still much that can be done from Earth, particularly from high altitude. To date, the loftiest major observatory in the world is on the summit of Mauna Kea, the extinct volcano in Big Island of Hawaii. (At least, one hopes that it is extinct; it neighbour, Mauna Loa, is extremely active!) The summit of Mauna Kea is almost 14,000 feet above sea-level, and this poses problems inasmuch as one's lungs take in only 39 per cent. of their normal oxygen ration, and great care has to be taken.

Of the telescopes of Mauna Kea, one – UKIRT, the United Kingdom Infra-Red Telescope – is of special interest. Water vapour is the enermy of the infra-red astronomer, but at 14,000 feet most of the moisture in our atmosphere lies below, and UKIRT has proved to be remarkably successful.

Beyond infra-red, and before we come to the radio range, we have the microwave region. These radiations are the target of a great new instrument, the James Clerk Maxwell Telescope. The

The Sky This Month

MARCH 1987 is not a good month for planetary observers. Venus, admittedly, is still a brilliant morning object, but it is well south of the celestial equator; the phase increases from 70 per cent. to almost 80 per cent., so that the planet is now gibbous. Mercury, the other inner planet, is too close to the Sun in the sky to be seen at all. Mars remains in the evening sky, but the apparent diameter has shrunk to less than 5 seconds of arc and the magnitude to +1.3, so that even powerful telescopes will show little surface detail. Jupiter sets soon after the Sun, and Saturn does not rise much before dawn. The Moon is full on the 15th, and new on the 29th.

The most interesting phenomenon is the solar eclipse of March 29th, which is "annular-total" – that is to say, annular along most of the track (so that a ring of sunlight is left showing round the dark disk of the Moon) and total briefly over a very restricted area. Totality will nowhere last for more than 8 seconds, and the eclipse will not be visible from the British Isles; the track begins in South America, crosses the South Atlantic Ocean, enters Africa near the Equator, and ends in the Indian Ocean. The partial phase can be seen from the extreme south-eastern area of Europe. The eclipse begins at 10h 03m GMT and ends at 15h 35m. This is a bad year for eclipses; there are only two, both of the Sun – the minimum possible. The other, annular eclipse on 23 September, is also invisible from any part of Britain.

With the lengthening period of daylight we are starting to lose the brilliant winter constellations; Orion sets in mid-evening, and so does Sirius. Ursa Major, the Great Bear or Plough, is gaining altitude in the north-east, while Cassiopeia with its characteristic W-form, is descending in the north-west, though neither the Bear nor Cassiopeia ever sets over Britain. The main spring constellation – Leo, the Lion – has now become prominent, high in the south; it is easily recognisable by its bright leading star, Regulus, and the curved pattern which makes up the so-called Sickle. Following Leo round is Virgo, the Virgin. It has only one first-magnitude star, Spica, but is very rich in faint galaxies; indeed, it is here that we find the Virgo cluster of galaxies, around 60,000,000 light-years away, and far more populous than our own Local Group. PE

'dish' is 15 metres is diametre, and consists of 276 individual panels, so arranged to make up the correct paraboloidal figure. It has been a major engineering feat; the main components of the telescope and its control system were delivered during 1985, but it was not until 4 December 1986 that the first radio signals were received. The telescope was first pointed at our nearest natural neighbour, the Moon, with a receiver tuned to a frequency of 230 GHz (1GHz = 1,000,000,000 cycles per second). The Moon, of course, depends entirely upon reflected sunlight, but it is hot during its day period, and, as expected, a strong signal was received. Next came tests upon the planets Jupiter and Mars, which were well placed for observation. (Hawaii, remember, is well to the south of Britain, and at present Jupiter and Mars are a long way south of the celestial equator, so that from Hawaii they are high up). Once again strong signals were received, and so far as we can tell the telescope is functioning perfectly.

The microwave region is of great importance in all branches of astrophysics, and it is hoped that the James Clerk Maxwell telescope will provide new information about star formation. At the moment we have a good idea of stellar evolution, but the very earliest stages – the condensation out of nebular material – are still uncertain, and microwave studies may fill in the gaps. There is, too, the microwave radiation which is coming in from all directions all the time. Unless our current theories are very much in error, this microwave background is the remnant of the "big bang" which occurred between 15,000 million and 20,000 million years ago – the birth of the universe as we know it today.

Before the detection of the microwave background, there was still strong support for the 'steady-state' theory, championed by Hoyle, Bondi and Gold, according to which there was no moment of creation, so that the universe has always existed and will exist forever; as old galaxies pass beyond the boundary of the observable universe, new ones are formed from material which is spontaneously created out of nothingness in the form of hydrogen atoms. It was, in fact, the microwave background which gave the coup de grâce to the steady-state hypothesis.

The James Clerk Maxwell Telescope – named after the great Scottish scientist of the last century – is largely British, with contributions from Holland. The Rutherford Appleton Laboratory at Chilton in Oxfordshire, in close collaboration with Cambridge University, was responsive for the design, development, construction and commissioning; there have been major contributions from Queen Mary College, Kent University and the Royal Observatory Edinburgh. From Holland, the main collaboration has come from Utrecht University, the National Foundation for Radio Astronomy Dwingeloo, and the Laboratory for Space Research in Groningen. The Dutch have always been in the forefront of radio and microwave astronomy, and they are maintaining this position now.

As the telescope comes into operation, we can only speculate as to what it will tell us, but without a doubt it will provide important advances in the near future – with the added advantage of being close to UKIRT and the various optical telescopes now scattered on the heights of Mauna Kea. It is an exciting prospect.

PE

PE 30 PLUS 30

PART THREE BY GRAHAM NALTY

An amp of excellence!

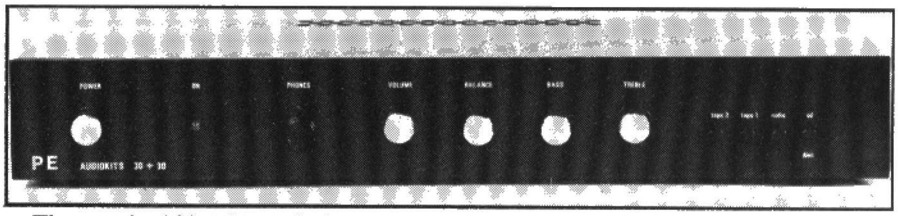
In this concluding part of the very high quality PE 30+30 amplifier, the power supply, wiring and a few points arising are discussed.

SINCE part one of the PE 30 + 30 was published, a few points have arisen that need further discussion.

In the first instance, I note with interest Robert Penfolds's comments about the noise on high level inputs with the volume control at minimum. In my experience, amplifiers with tone controls and their circuitry are more noisy than those without them. It is quite possible that using a polycarbonate capacitor for C22 allows more hiss through than a polyester one, and even more than the commonly used electrolytics. If any readers have any ideas on reducing the noise of the tone control stage without sacificing sound quality, I would be interested to know.

The arrangements for the output stage may cause a little confusion, so I will explain in a bit more detail. The standard 30 + 30 uses one pair of output transistors per channel with OR15 wirewound resistors connected to each emitter (R49 and R50). The use of a low value for these resistors reduces distortion, but is dependant on the close thermal tracking between the bias transistor Tr19 with Tr20 and Tr21, which should be placed only in the positions shown on the component overlay. If you wish to build a high current version with two pairs of output transistors, then the thermal tracking between the outer transistors and bias transistor is reduced and a larger value of emitter resistors recommended. This is provided by two 1 Ohm resistors in parallel, which should be at least half watt rating, and preferably one watt. The Holco resistors suggested for the improved version result in a large improvement in sound over standard metal film or wirewound resistors. The power rating of TIP131 and TIP136 is 70 watts, and is lower than the other recommended types. Whilst they are satisfactory when used in pairs in a high current version, the higher power types are more suitable in the standard 30 + 30.

Some transformers for audio amplifiers can produce audible mechanical noise when the amplifier is playing. The transformers supplied with PE 30 + 30 kits are specially manufactured for low noise, though cost a little more.



The standard 30 + 30 can be increased in power by changing the transformer secondary from 22v-0-22v to 25v-0-25v, but at the same time, capacitors rated at 35v should be changed to 40v, the output transistors doubled up, and their emitter resistors changed from one OR15 to two pairs of 1R0 in parallel. Also, it is a good idea to increase the reservoirs C35 and C36 from 6800, μF to 10,000μF. Each reservoir capacitor should be attached to the case by two nylon cable ties.

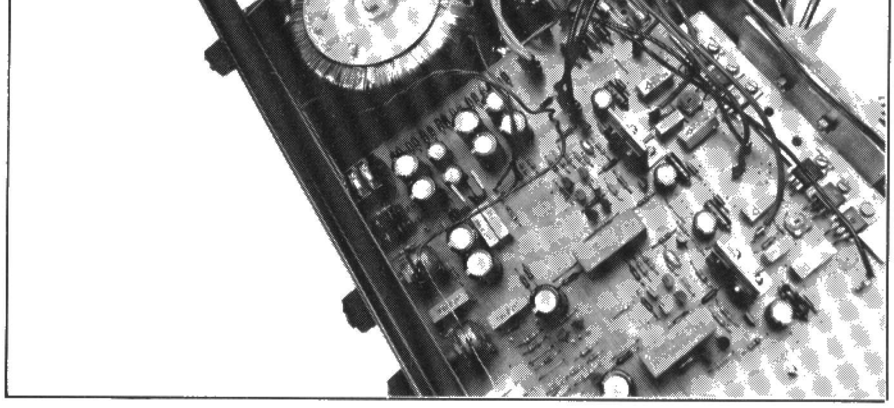
Cable lengths are shown primarily for constructors using high perfomance audio cables which may cost several pounds per metre length. The most suitable audio quality cabnle for internal wiring is Kimber cable which is available in three colours, red, blue and black. Where two colours are shown above, the first colour is used on standard kits and the second is the recommended colour when using Kimber cable. Kimber cable is directional (its sounds better one way), and the arrow markers on the cable should point in the direction from cartridge to speaker, or from power supply to circuitry.

CORRECTIONS

PE Feb 87, page 43, Fig.2. The left hand end of R34 should be connected to the emitter of Tr8, and not to Tr9, Tr10 and Tr13. The bottom end of R30 should not be connected to the junction of R32 and R33.

PE March 87, page 50. Add R68 and R69 after R59. Delete R65 and D31. Add: R48/10 Ohms ½w metal film/10 Ohms Holco H2 1W. For improved version: C21 use 47OpF EXFS/RP. C35/ C36 FILMCAP DNM can be substituted. C2 use 8nF EXFS/RP. IC2 use MC7815CT.

Page 51. Add R63 prior to R64. PE



CABLE LENGTHS

Cable	Length (cms)	Colour
L Disc input signal	5	Blue
L Disc input earth	5	Green, Black
R Disc input signal	8	Brown, Red
R Disc input earth	8	Green, Black
L CD signal	16	Blue
CD earth	16	Green, Black
R CD signal	16	Brown, Red
L Radio signal	16	Blue
Radio earth	16	Green, Black
R Radio signal	16	Brown, Red
L Speaker +	13	Black, Blue
L Speaker −	10	Green, Black
R Speaker +	10	Brown, Red
R Speaker −	10	Green, Black
L Headphone	16	Red, Blue
R Headphone	13	Red
Headphone earth	9	Green, Black
C35 + to rectifiers	10	Red
C35 + to L Channel	20	Red
C35 + to R Channel	14	Red
C36 − to Rectifiers	6	Black, Blue
C36 − to L Channel	22	Black, Blue
C36 − to R Channel	16	Black, Blue
C35 − to earth	13	Green, Black
C36 + to earth	8	Green Black
Mains fuse-holder to mains switch	25	Red
LED +	14	Brown*
LED −	14	Green*
Chasis earth to pcb	13	Green*

*Audio quality cables not required.

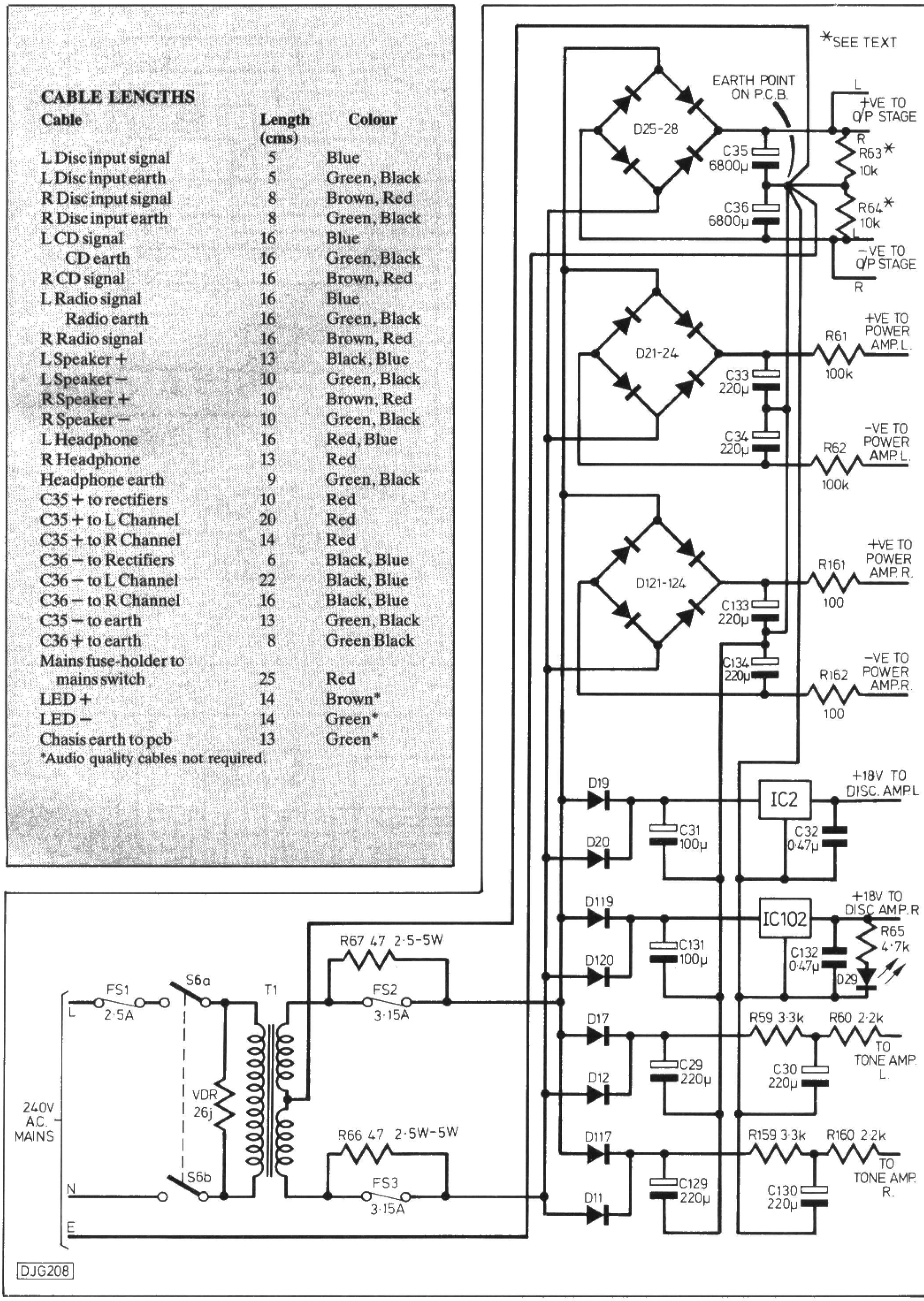
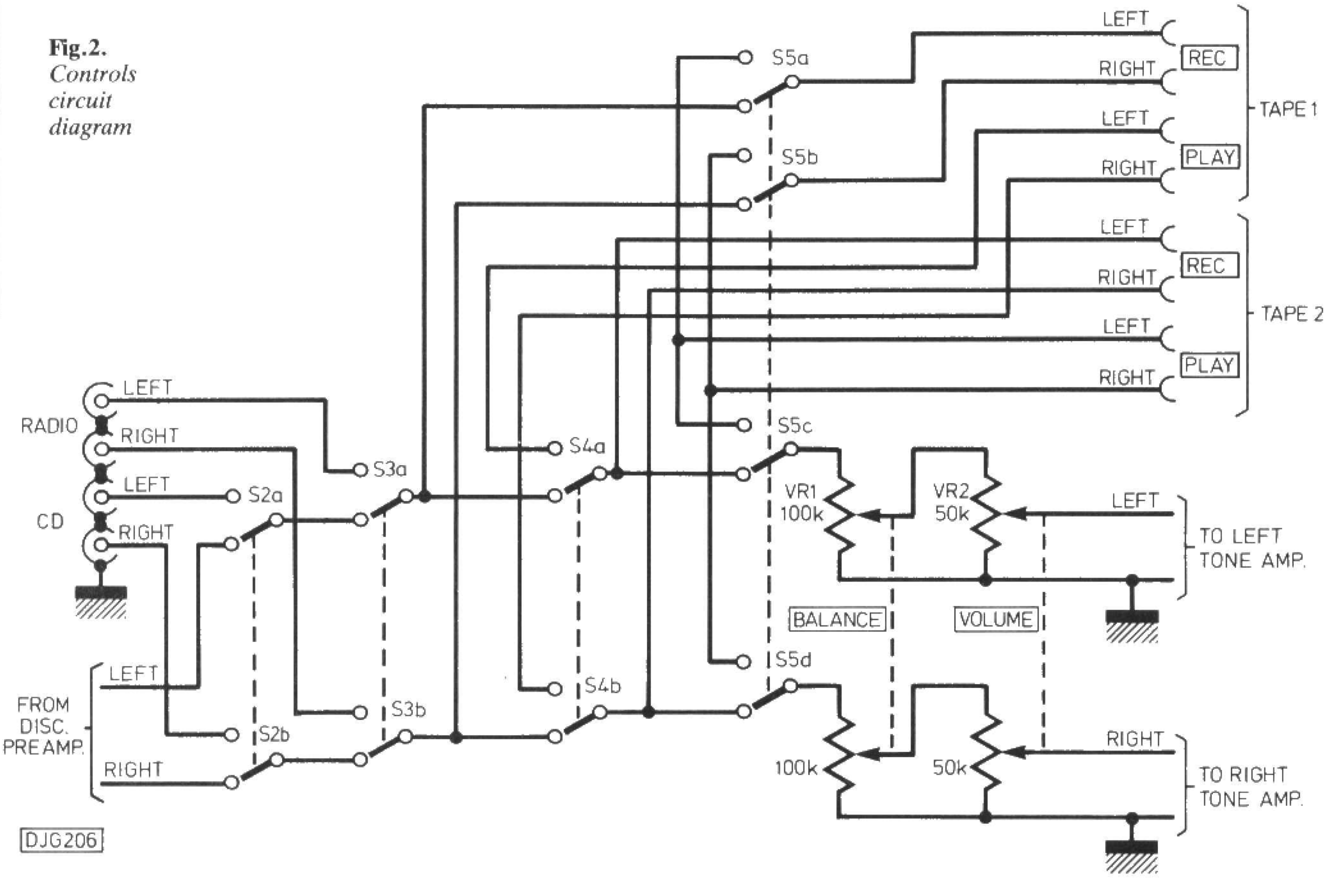


Fig.1. *Power supply circuit diagram*

Fig.2. *Controls circuit diagram*



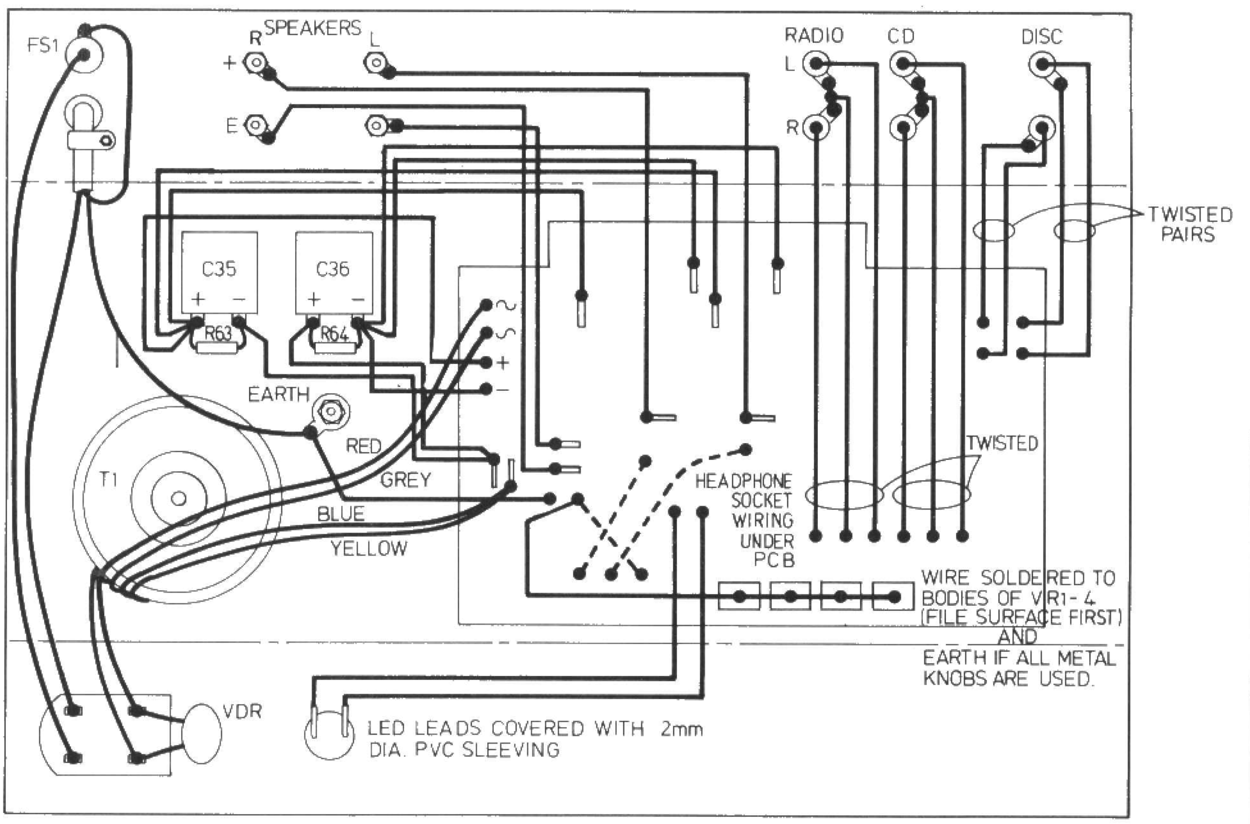


Fig.3. *Wiring diagram*

DIRECT CURRENT MOTORS

PART TWO BY BRIAN BROOKS

Characteristics, performance & control circuits.

In the second part, this article looks at passive and active central circuits for small D.C. motors.

IN PART ONE of this article the relationships between voltage, current, torque and speed were established for d.c. motors. In this part of the article various methods of motor control will be demonstrated which make use of these relationships.

SIMPLE SYSTEMS

A) Series Resistance

The simplest form of motor control is that used in model railways and racetracks – the series resistor. Fig.1. shows the circuit and the torque/speed curves for various values of series resistance. Note first of all that the external series resistor limits the motor performance in exactly the same way that the internal motor resistance does. The effect on the torque and speed characteristics is shown in Fig.1. (a) and (b) for several values of RV. The most obvious feature of Fig.1. (a) is that the motor is controlled indirectly by the effect of the torque/speed characteristics of the motor load. An idealised load-line is shown in Fig.1. (a). The motor speeds corresponding to the various settings of RV for this particular load are found by the intersection of the load-line and the torque/speed lines. With the ideal load shown the speed control is quite reasonable. It is non-linear, but because the best control is obtained at low speeds, this is an advantage in model applications. The same motor curves are shown in Fig.1. (b) but this time with a more realistic 'imperfect' load. This load has an initial starting torque requirement to overcome the static frictional forces and additional non-linear 'stiction' forces which resist the initial movement of the motor. Once the motor begins to move, the stiction forces drop to zero and the motor requires less torque than the starting torque to run slowly.

This non-linear behaviour at low speeds exists in all systems but is particularly evident in smaller motors usings simple bearings and brushes. The effect is a familiar one to those who have played with model trains. The controller must be advanced to a certain point before the train will start, whereupon the train speed jumps abruptly (and unrealistically) to a 'minimum start speed'. Fig.1. (b) shows this effect very clearly by the intersection of the motor torque/speed curve for RV = 1 OR (approximately) with the load line. The two points of intersection are the starting torque and the 'minimum start speed' respectively. Above the minimum start speed the imperfect load is controlled reasonably well. Note also that once the motor has started, it is possible to reduce the speed below the minimum start speed by backing off the controller, i.e. increasing RV. This is another technique with which the model railway enthusiast will no doubt be familiar.

All that has been considered so far is a simple load with constant torque/speed characteristics. If the motor load conditions change, for example due to a model train encountering a gradient, the motor speed and torque will change to meet the new load-line. Fig.2. shows two possible load lines crossing a slow speed setting from the graphs of Fig.1., (RV = 2R approx). The new 'Higher Load' demands an increased torque which is obtained at a lower speed where the new load-line crosses the torque/speed line. Although the extra torque required is quite modest, the speed falls to almost half. At lower torque settings the effect is even worse and the motor speed varies widely in response to load changes. This method of control is very limited and has very few advantages other than simplicity.

B) Variable Voltage

The second method of motor control is far superior to the series resistance method, but is more complicated. The extra complication is not very important now that monolithic voltage regulators and high gain power transistors are available. As the name implies, the motor is fed with a variable voltage from a low impedance source.

Fig.3a. shows the performance curves for several values of motor voltage. V1 is the standard terminal voltage and the motor torque/speed characteristic is exactly the same as in Fig.1. where RV = 0. At lower voltages V2, V3, etc. the stall-torque and the no-load speed both decrease and a set of parallel torque/speed curves results. When the two load-lines from Fig.2. are drawn, the improved performance is shown immediately by the larger increase in torque, accompanied by a smaller decrease in speed. This is closer to the ideal characteristic where a large increase in torque would produce no change in speed.

There are two other advantages of this method. The first is that the motor speed is linearly related to the applied voltage. This is helpful when motors are used as simple drive systems, because fixed-ratio voltage dividers can be used to provide a range of speeds.

The second advantage – attention model railway enthusiasts – is that the low speed performance is improved and the 'Minimum Start Speed' of the real load in Fig.2b. is greatly reduced. Fig.3b. shows this improvement graphically. The extra complication of this method of control is its main disadvantage.

One other disadvantage is that at low speed settings there is only a small voltage applied to the motor. This can give rise to problems when there is poor contact between the brushes and the commutator due to wear, corrosion, or design economies. In some circumstances the voltage applied will be unable to break down the surface contamination, with the result that the motor will not start. This contrasts with the series resistance method of control where the full supply voltage is available and appears instantly across any high resistance contacts – even at low speed settings.

These two simple methods of control are adequate in themselves for some simpler motor control applications. Neither of them can pretend to offer anything like 'constant speed' performance, and low speed running can only be obtained by means of low

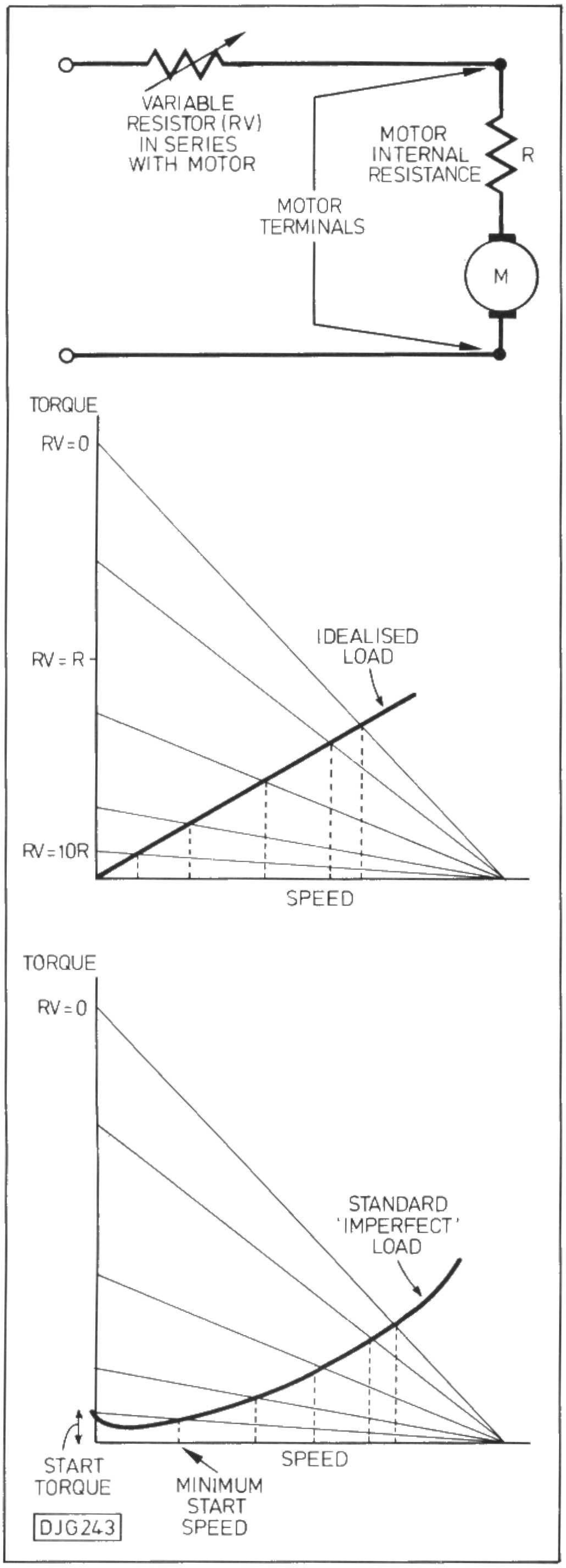
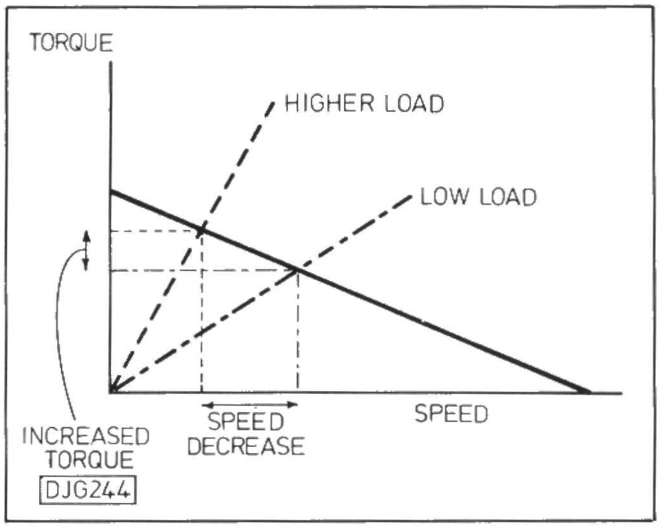


Fig.1. *D.C. motor series resistance speed control circuit and characteristics.*



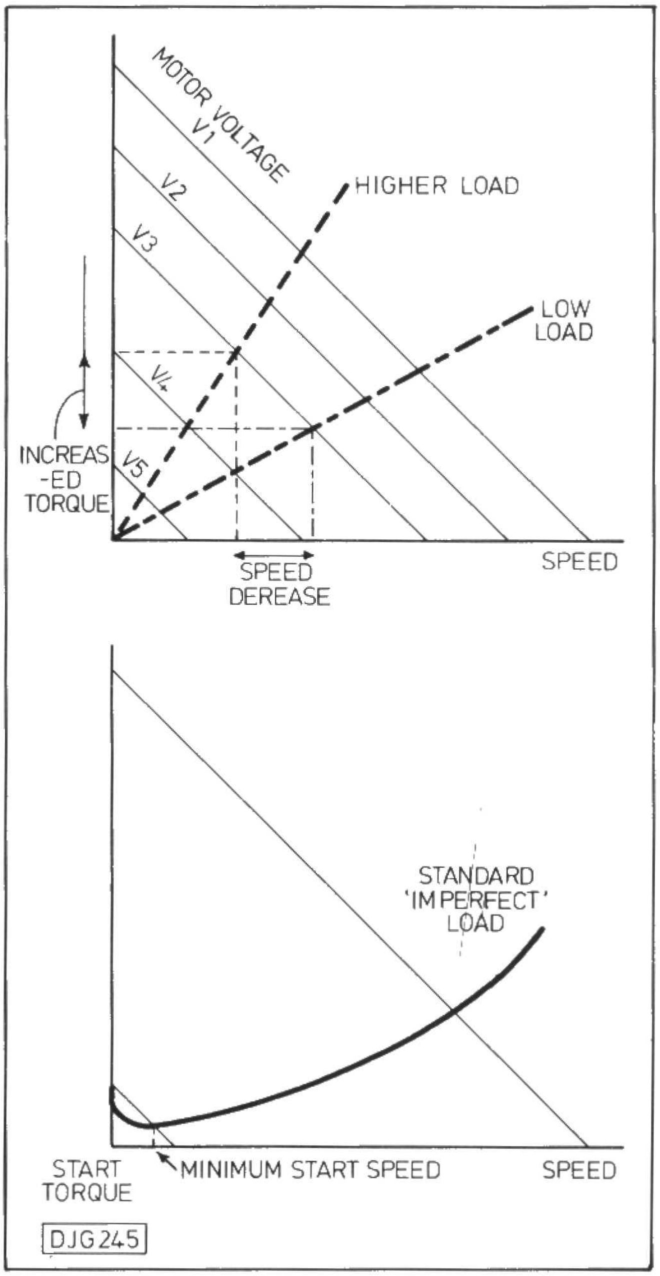


Fig.2. *(Top) Effect of changing load.*

Fig.3. *(Bottom) Variable voltage speed control.*

torque. The ideal controller would allow constant speed to be obtained over a wide range of loads and with full rated motor torque available at all speeds. These desirable characteristics can be achieved by the use of 'active' circuits which apply speed and current sensing feedback techniques to modify the power fed to the motor and force it to behave well. A small amount of circuitry and a cheap motor can be combined to produce excellent quality drives for a wide range of applications.

ACTIVE CONTROL SYSTEMS

The main requirement for an active d.c. motor control system is that it should adjust the power applied to the motor to maintain constant speed for varying loads.

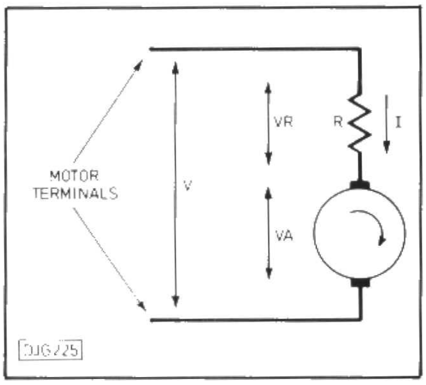


Fig.4.

In the first part of these articles the simple model for a d.c. permanent magnet motor was introduced. This consists of a perfect motor with no winding resistance, in series with a separate resistor which represents the effective total winding resistance measured across the motor terminals. Fig.4. is a repeat of the model schematic drawing from part one.

As the motor rotates the ideal rotor generates a voltage VA which opposes the applied voltage and is directly proportional to the motor speed. This is called the Back EMF or Counter EMF. A frictionless unloaded motor would require no current and would run at a speed where the counter EMF was exactly equal to the applied motor terminal voltage V. In the real world the motor requires current to produce power to oppose the air and bearing friction. This current must pass through the winding resistance R and so there is a voltage drop of VR = I x R) between the ideal rotor voltage VA and the applied voltage V. If a load is now applied to the motor, the motor current increases further to supply the necessary torque (torque is directly proportional to motor current). This increased current results in an increased voltage drop across VR and therefore VA is now much smaller than the applied motor voltage V. The motor speed thus falls as the voltage drop across R increases due to increased motor current.

To maintain constant speed regardless of torque, a way must be found to keep VA constant with motor current and the voltage drop across R. As the value of R is constant and motor current can be measured, it is a simple matter to calculate the votage dropped across R (VR). Once this is known, a voltage equal to VR can be added to the motor terminal voltage so that VA remains constant regardless of motor current.

A simplified circuit which will achieve this is shown in Fig.5. Current flowing through the motor produces a small voltage drop across the current sensing resistor RC. This voltage drop is amplified and fed back to the voltage regulator REG so that the output voltage rises as the current increases. The degree of this increase is such that it exactly equals the Voltage drop VR across the motor internal resistance.

Fig.6. shows the ideal motor voltage curve plotted against torque for the circuit of Fig.5. Note particularly that the voltage VA across the ideal rotor remains constant from zero torque right up to the maximum 'stall' torque. The shaded area represents the added feedback voltage which exactly equals VR. By varying the amount of feedback that is applied, the motor characteristics can be changed to produce whatever torque/speed characteristic is required. The feedback level shown is producing a 'neutral' constant speed response. This is idealised for simplicity, but even in practice very good results can be obtained with the correct amount of feedback.

The motor speed is varied whilst maintaining the full feedback speed stability by altering the voltage output from the regulator. This method of feedback control is practically ideal for small motors where power dissipation in the regulator is managable. At higher power levels, other techniques such as pulse width modulation and thyristor control are better. More about these and a practical feedback controller project will be presented in the next part. PE

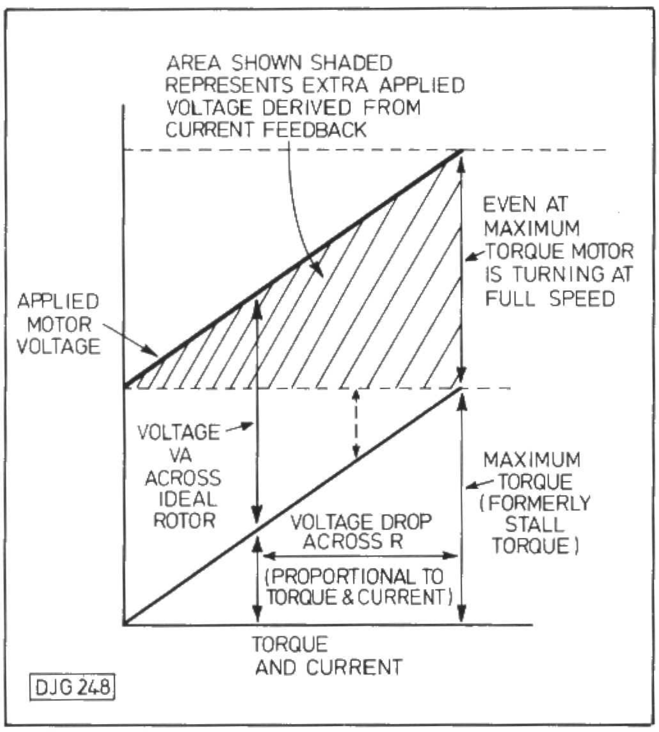


Fig.5. *Current feedback simplified circuit.*

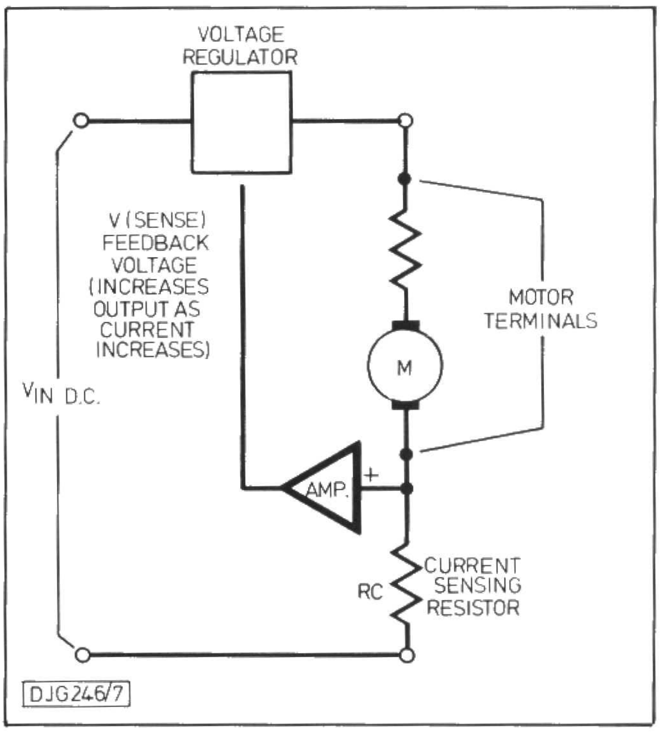


Fig.6. *Current feedback circuit voltage characteristics.*

INDUSTRY NOTEBOOK

REPORT BY TOM IVALL – PE's NEXUS

Human motivations in the industry

Reasons for being involved in a business can vary widely, but the higher up the corporate tree they go, the more essential it is that individuals keep in close touch with the interests of the industry.

LET US continue our discussion, started last month, on the interaction of the electronics industry with society at large – and hence with the lives of individuals like you and me.

To do this we must first look inside the industry itself, to see what sort of animal it is. Although I've been talking about the industry as if it were a clear entity, it is in fact rather amorphous. It holds together in a very loose kind of way. For example, the commonality of technology is really just a concept, a categorisation made by the observer. And things like the trade deficit which the British electronics industry has with the rest of the world are similarly just statistics, the result of analysis by economists and businessmen.

Certainly there is some degree of mutual dependence. An equipment maker depends on reliable supplies of particular components from firms specialising in these products. Equally the component manufacturers rely on the equipment makers to provide them with custom and therefore income. If the supply of a particular type of i.c. dries up, it can be anything from inconvenient to disastrous for the equipment firm. But in practice the company switches its custom to another component supplier, and there is not much sentiment or loyalty affecting the issue. Such patterns of mutual dependence and shared iterests are reflected in the existence of trade associations like Electronic Engineering Association in the UK.

But when you get down to the level of the individual companies forming the industry, the picture changes. Here the motivations of humans are powerful and crucial. For example, anyone who starts up a new firm, perhaps with partners, must be highly motivated to do it at all. One doesn't just drift into such an undertaking. Equally, in a small group of people, say a development team within a large company, the presence or absence of certain individuals, the knowledge, experience and performance of these persons, can be crucial to the task in hand. Companies talk about 'key personnel' and this is what they mean.

So what are the motivations of employees in companies? If you walk into an electronics firm from the outside world you immediately get a snapshot of people working away on their own or in small groups and apparently independently. There is no obvious sign of general compulsion, like a slave driver with a whip, but they are all occupied and immersed in their separate tasks. Even the slackers, intent on getting through the day with as little expenditure of effort as possible, will be putting a good deal of ingenuity into the task of appearing to work, or deluding themselves that they are doing something productive.

There is an old saw that if you ask three workers on the same production line what they are actually doing, one will say "I'm making a living", the second will say (for example) "I'm assembling these components on this printed-circuit board" and the third will say (for example) "I'm helping to build a process control computer that will improve the efficiency of an ICI chemical plant." This is grossly over-simplified, of course, but it does illustrate the fact that individuals can have different views of the same work and different reasons for doing it.

Obviously most of us have to make a living. This is a general requirement. But we all know people for whom job satisfaction is more important than the amount of the salary. For others the primary consideration is that their job enables them to live in a certain area. Professionals often see their present job as a stepping-stone in a planned career. Some people, who might otherwise be lonely, rate the companionship offered by work more highly than the money attached. And, of course, with the present high level of unemployment, many are glad to get any kind of job at all and they work simply to keep it.

In a good firm all these different drives and interests work together harmoniously, though some conflicts and forced compromises may be inevitable. When this happens it is a sign of good management.

The further you go up the hierachy of a company the more important become the business imperatives. The production director or the sales director of an electronics company may be preoccupied with problems and targets in these particular areas, but they also have wider responsibilities to their fellow directors, to the profit and loss account, to the shareholders, and to the survival of the company as a whole in a competitive environment.

At this level of higher management the traditional view is that there is one predominant objective: to maximise profits. This is certainly true for small companies where the few individuals forming the management are also the owners of the firm: they have a lot to gain or lose. But the larger the company the more it tends to separate the functions of control and ownership. The firm is controlled by employed managers and owned by shareholders.

Generally speaking the shareholders, who might be pension funds or other financial institutions, do not get involved in management as long as their dividends are satisfactory and the market values of their holdings are maintained. Equally, the managers do not have any direct concern or responsibility for the capital invested and its returns. Consequently they are not primarily motivated to maximise profits to keep up share prices and dividends on the stock market.

So in these circumstances of divorce between control and ownership the senior managers tend to be motivated by other things that give them satisfaction. It could be a higher salary, enjoyment of greater power or status, a larger office or company car, something in the Honours List, more free time for golf, or any of a wide range of perks. This situation can be dangerous if the managers spend too much time and effort chasing things which are not essential to the business success of the company. Then the shareholders might have to intervene. PE

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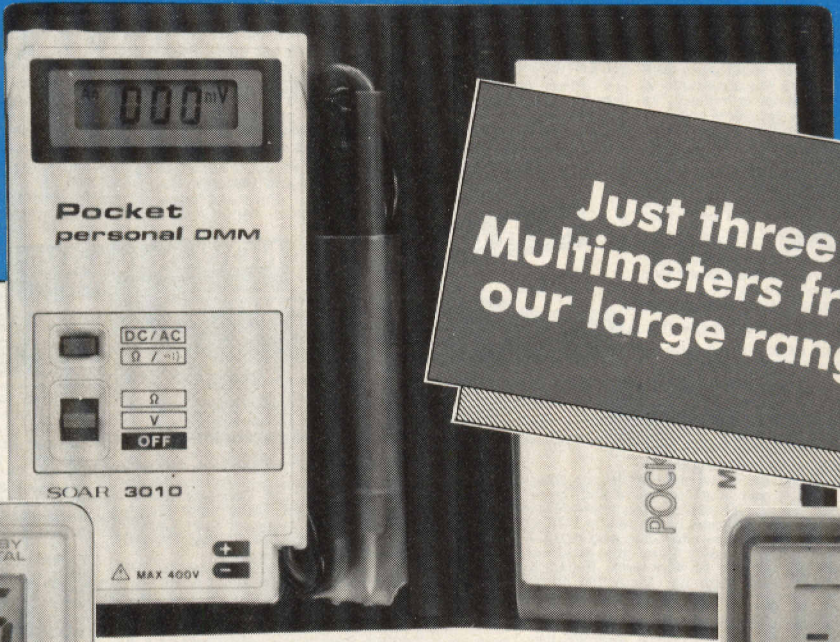

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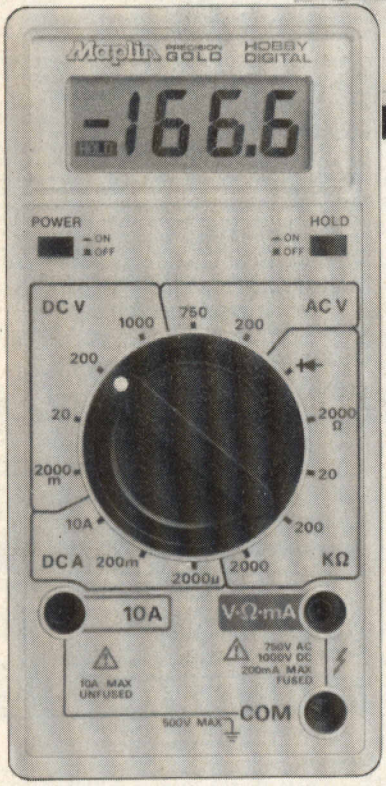

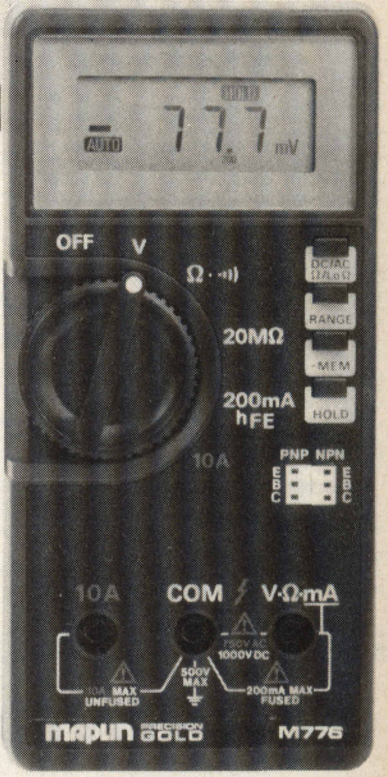

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